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TEXAS EMISSIONS AND ENERGY CALCULATOR (eCALC): Documentation of Analysis Methods

Report to the
Texas Commission on Environmental Quality

TCEQ

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Disclaimer

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1 EXECUTIVE SUMMARY

This report provides documentation about the Energy Systems Laboratory's Emissions and Energy Calculator (eCALC), including information about the web structure, new building models, and community projects. In each of the sections a description of the basic user input is provided, and a description of the analysis that eCALC performs once the use submits a project for analysis. This report also provides a brief summary of the literature reviews for the analysis methods that were developed to document the uncertainty reported in the literature, including: F-Chart, PV F-Chart, ASHRAE's Inverse Model Toolkit (IMT), Cool Roofs, and the DOE-2 program. This report also provides a description of the methods used to assemble actual weather data files for 1999 through 2003 for use in eCALC.

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2 GENERAL

In the Fall of 2003, the Energy Systems Laboratory (ESL) formed a partnership with the Texas Commission for Environmental Quality (TCEQ), and the USEPA, to enhance the Emissions Reduction Calculator. Since then, the Laboratory has worked closely with the TCEQ, using funding provided by the USEPA, to enhance the calculator. This section of the report provides additional details about the web-based structure of the Laboratory's web-based calculator, including a complete description of each of the major modules contained in the calculator.

2.1 Web structure

Figure 1 provides a block diagram of the various software elements contained in the ESL's web-based emissions calculator. The calculator is composed of four major elements, including: a web interface, a calculation engine, a weather database, and a general project/operations database. The web interface handles the interaction with the user, which includes receiving the general project information (including their email address for returning the results). Instructions from the user are passed to the calculation engine along with other information kept in the calculator's libraries. Once the user decides on a particular analysis, the calculator then routes their information into one of several legacy models, including the DOE-2 program for building simulation analysis (LBNL 2000)[1], the F-CHART program for solar thermal analysis[2], and PV F-CHART program for solar photovoltaic analysis (Haberl 2004b)[3], the ASHRAE Inverse Model Toolkit (IMT) for monthly utility billing analysis used in the monthly municipal, traffic light, street light, water, waste-water and wind energy analyses.[4] A special-purpose peak-extractor has also been developed for extracting either the peak day use (i.e., DOE-2 simulations), or the coefficients that can derive the peak day use[5]. Annual and peak-day savings are then passed to the USEPA's eGRID database, where specific emissions data are contained for the electric utility provider associated with the user.

Figure 2 illustrates the screen that the eCALC user sees to select the different models. There are three groups of models, including: New Building Models, Community Projects, and Renewables. Those in the New Building Models group include single-family residential, multi-family residential, and two choices of commercial buildings, including: office and retail models which represent the two largest groups of commercial buildings in Texas, according to the USDOE's Energy Information Agency's Commercial Building Energy Characteristics (CBECS 1995) database. The second group includes models for Community Projects, including: two municipal models (new construction and retrofit), two street light models (new construction and retrofit), two traffic light models (new construction and retrofit), a retrofit model for municipal water supply projects, and a retrofit model for municipal waste-water projects. In the third category, three models for renewable energy projects includes: solar photovoltaic, two solar thermal models (pool and DHW), and a model for wind energy systems.

[1] Additional information on the DOE-2 program can be found at the Lawrence Berkeley National Laboratory's website: www.lbnl.gov.

[2] Additional information on the F-Chart program can be found at Klein, S. A., W.A. Beckman, 1993. F-Chart Solar Energy System Analysis: Version 6.17W, F-Chart Software, 4406 Fox Bluff Road, Middleton, Wisc. 53562, www.fchart.com.

[3] Additional information of the PV F-Chart program can be found at F-Chart Solar Energy System Analysis: Version 6.17W, F-Chart Software, 4406 Fox Bluff Road, Middleton, Wisc. 53562, www.fchart.com.

[4] Additional information on the ASHRAE Inverse Model Toolkit can be found at Kissock, K., J.S. Haberl, and D.E. Claridge. 2002. Development of a Toolkit for Calculating Linear, Change-point Linear and Multiple-Linear Inverse Building Energy Analysis Models. Final Report for ASHRAE Research Project 1050-RP.

[5] A description of the peak day extractor was provided in the Laboratory's 2003 report to the TCEQ, and can be found in Haberl, J., Im, P., Culp, C. 2004. NOx Emissions Reductions From Implementation of the 2000 IECC/IRC Conservation Code to Residential Construction in Texas. *Proceedings of the Fourteenth Symposium on Improving Building Systems in Hot and Humid Climates*, Texas A&M University, Richardson, Texas, accepted for publication (February), pp. 139-150.

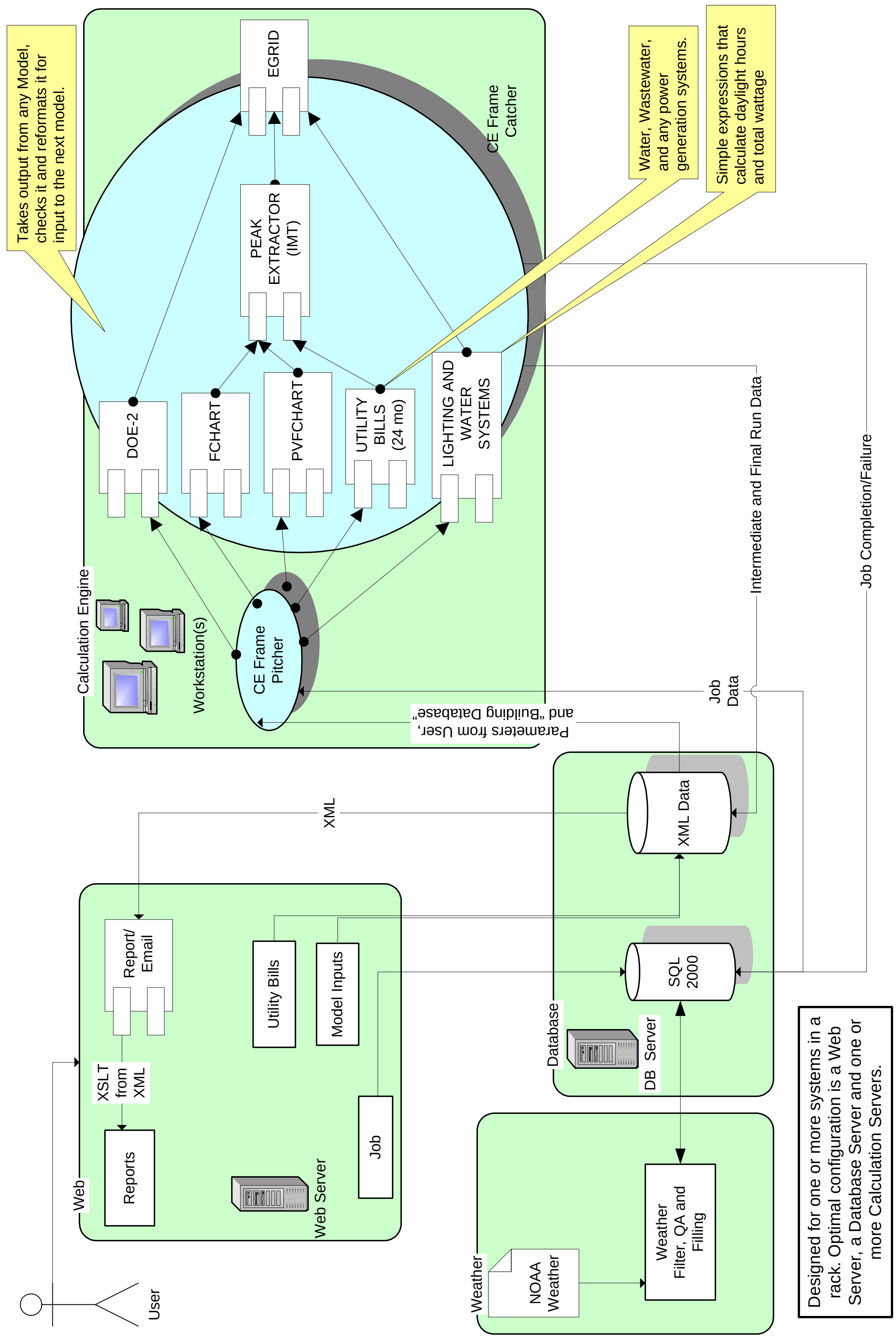

Figure 1: Block-diagram showing interactive-functionality of the emissions reduction calculator.

Figure 2: Laboratory's Enhanced Emissions Reduction Calculator (Main eCALC Screen).

2.2 New Building Models

The emissions calculator calculates the emissions reductions from the implementation of the Texas Building Energy Performance Standards (TBEPS) by comparing the energy use of a user's building against the energy use of a building that would have been built prior to TBEPS (Pre-code). The calculator also allows for the calculation of energy savings and the resultant emissions reductions for buildings that are more efficient than the code by allowing the user to compare their energy use against a similar building that is built to be compliant with the 2000/2001 IECC for residential single-family and multi-family construction, and the ASHRAE Standard 90.1-1999 for commercial buildings.

2.2.1 Single-family User Input

The user input screens for the single-family model can be seen in Figure 3 through Figure 9. In Figure 3, the user is directed to input their project information, including an email address that will receive the analysis results from the calculator. The user also must provide the county in which the project is located.

This information is used to configure the default Power Control Authority (PCA), or Power Provider, which is shown as the next input. In this input, the user can select from one or more PCAs that provide power to that county, according to the county-PCA matrix provided by the Texas Public Utilities Commission. The user can also provide information about the available utilities, which is intended to be used in the residential retrofit analysis.

Once the user has provided the information requested in Figure 3, the user is automatically directed to Figure 4, the express entry screen for single-family residential. In Figure 4, the required DOE-2 inputs (Table 3) have been reduced to twelve entries that are required for an express analysis. If the user desires additional details about the input parameters, they can switch to the detailed calculation, which takes them to the input screens shown in Figure 5 to Figure 8. In Figure 5, additional inputs are allowed for the number of people in the building and the number of bedrooms, which is used in the IECC-required sizing of the Domestic Water Heating system. The user is also allowed to reconfigure the simulation to include a crawlspace, versus the slab-on-grade simulation that is the default.

In Figure 6, the user is allowed to change the shape of the shading provided by the building's eaves on a given orientation. Initially, the building is configured without any significant shading from the eaves. In Figure 7, additional information is requested for the building construction, including such features as the color of the roof and walls, which changes the solar absorption. Also, the user is allowed to change specific details about the windows including the type of frame, the u-factor, the solar heat gain coefficient, and the size of the windows according to the window-to-wall ratio (%). The user is also allowed to change the insulation on the floor, i.e., slab-on-grade or crawl space.

Finally, in Figure 8, the user is allowed to provide additional details about the heating/cooling/DHW systems, including the fuel type, air conditioner efficiency (Seasonal Energy Efficiency Ratio, SEER), heat pump efficiency (Heating Seasonal Performance Factor, HSPF), domestic water heater efficiency (%), and gas furnace efficiency (Annual Fuel Utilization Efficiency, AFUE). The user can also change the number of pilot lights associated with the gas furnace and gas DHW.

When the user is completed with their project input, they can submit the project for analysis, which is acknowledged by the emissions calculator in Figure 9.

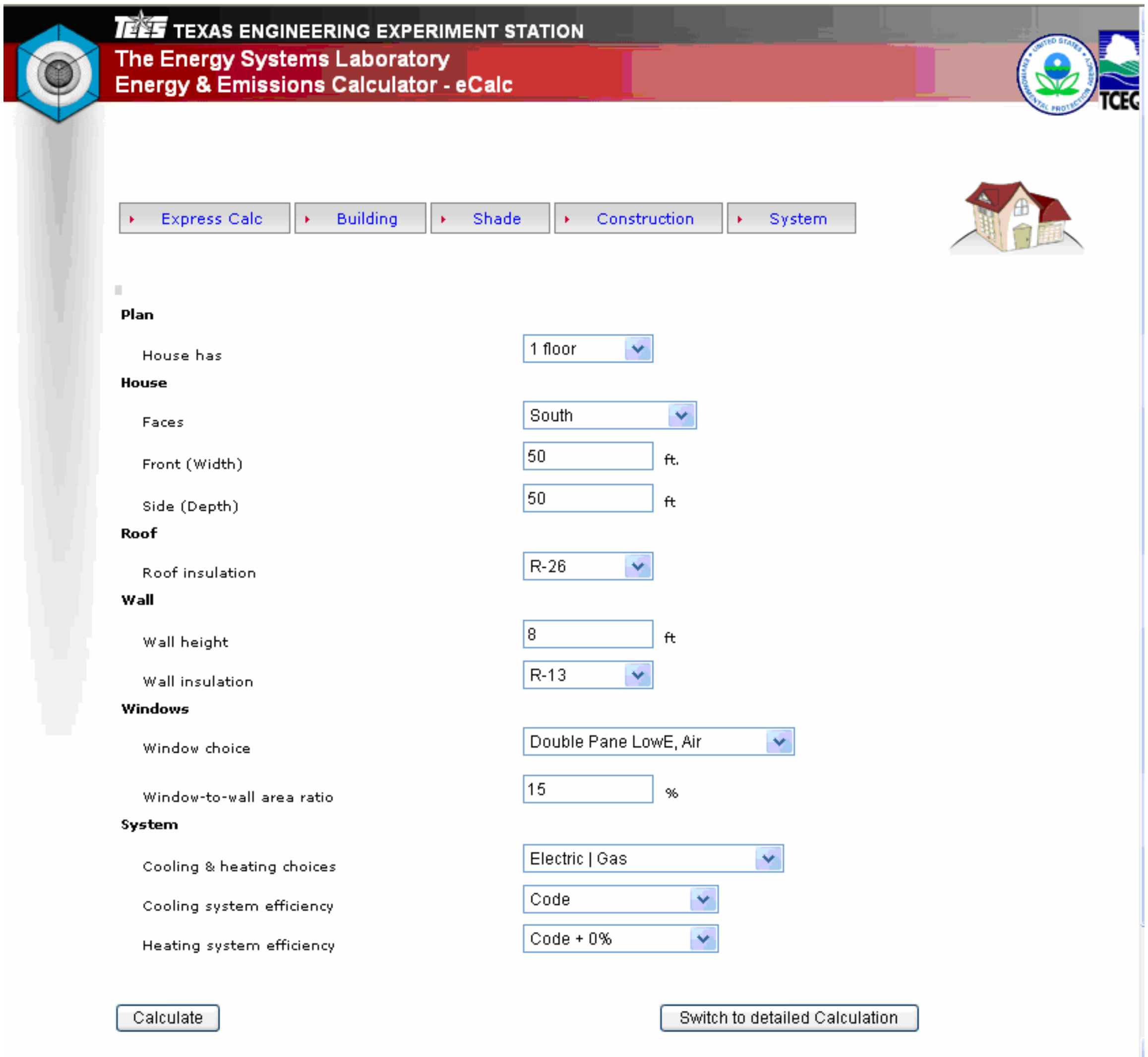

Figure 3: Single-family Residence Data Entry Screen (Project Input).

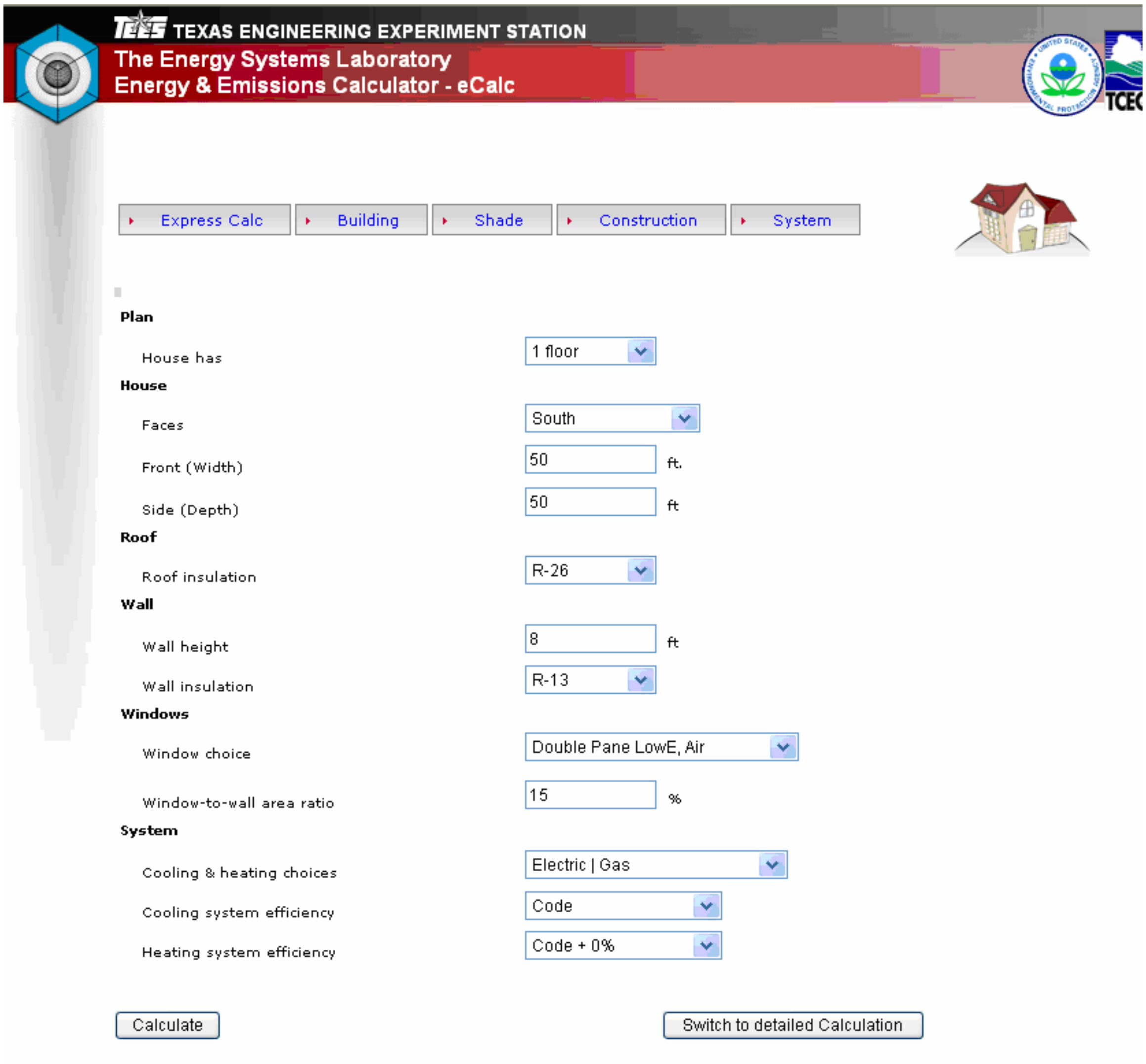

Figure 4: Single-family Residence Data Entry Screen (Express Input).

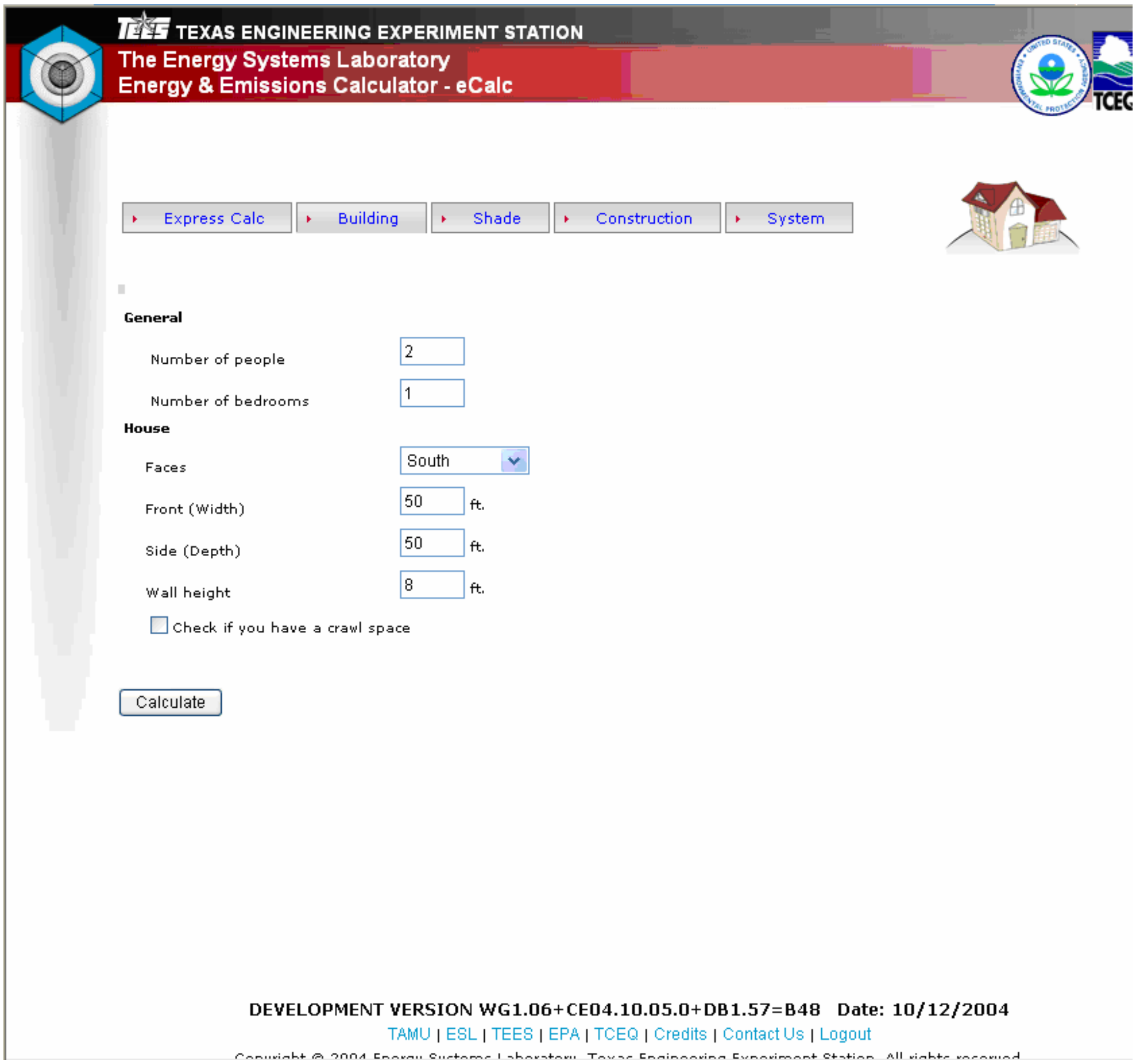

Figure 5: Single-family Residence Data Entry Screen (Detailed Building Input).

Figure 6: Single-family Residence Data Entry Screen (Detailed Shade Input).

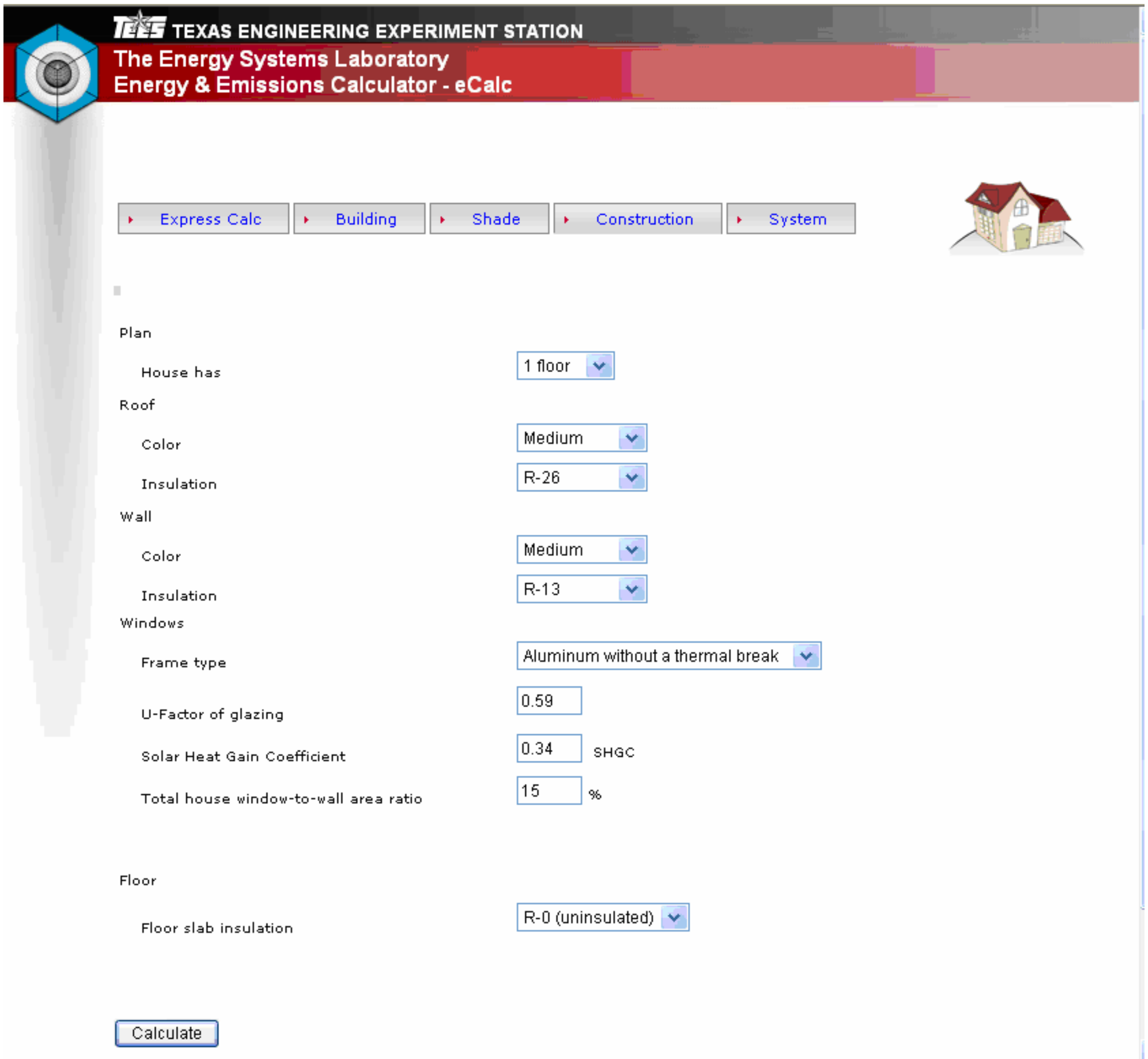

Figure 7: Single-family Residence Data Entry Screen (Detailed Construction Input).

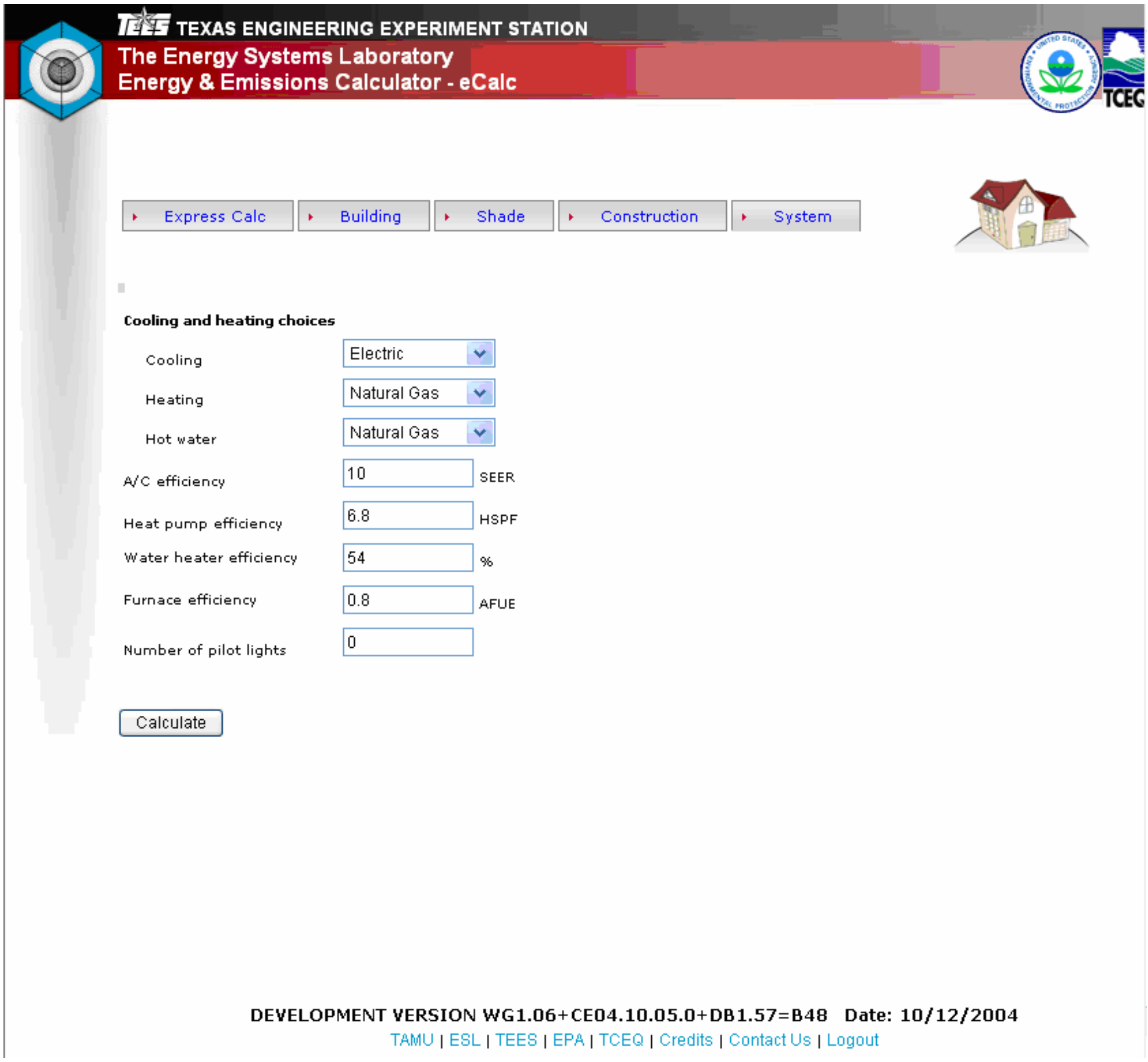

Figure 8: Single-family Residence Data Entry Screen (Detailed System Input).

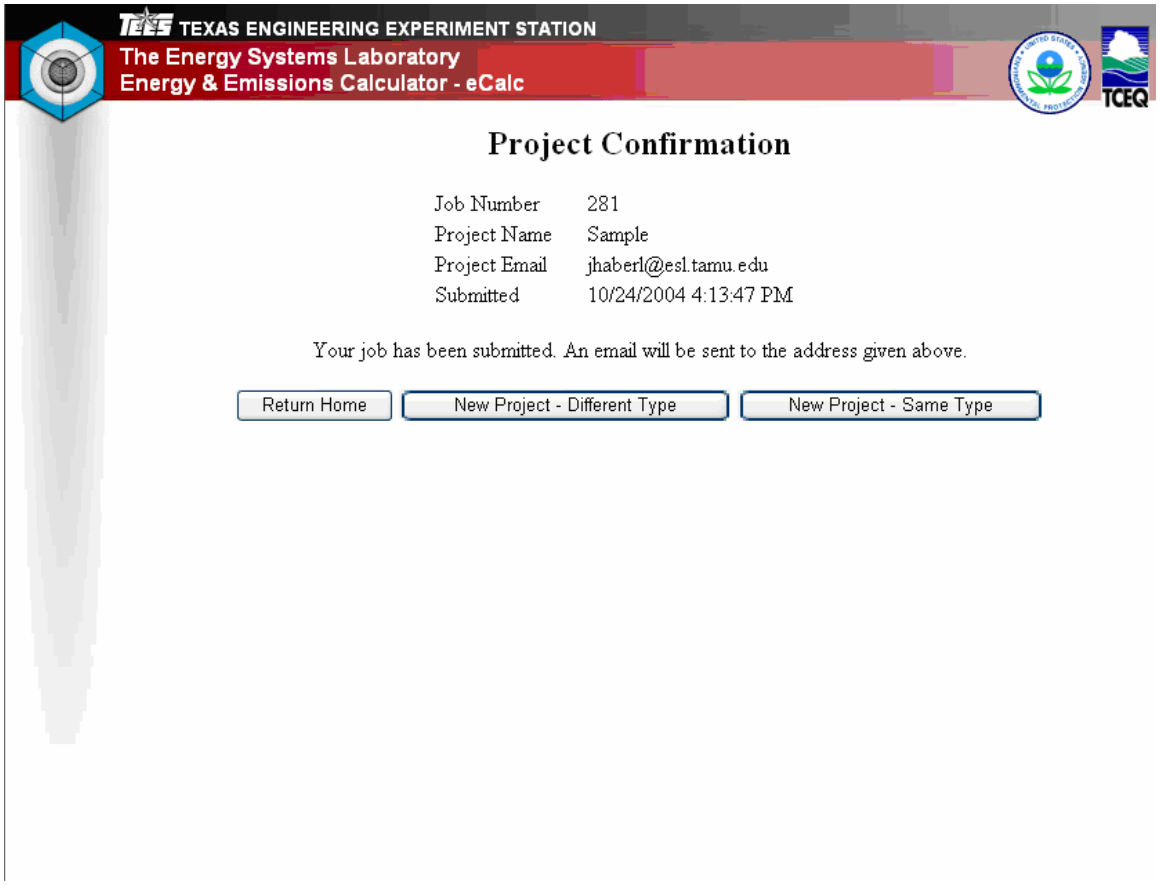

Figure 9: Single-family Residence Project Confirmation Screen.

2.2.2 Single-family and Multi-family Analysis Description

When the user submits their residential project for analysis, the emissions calculator performs a series of calculations, as indicated in Figure 10. For each analysis, the user's building description input is compared with pre-code values (Table 1)[6], and code-compliant values (Table 2)[7]. These user-defined input parameters are then passed to the DOE-2 simulation program along with additional, pre-defined parameters (Table 3 – Single-Family, Table 4 – Multi-Family) and the 1999 weather data[8] associated with the county. The DOE-2 program then generates three output files (i.e., one output for pre-code simulation, one for the code-compliant simulation, and one for the user-defined building) as shown in Table 5 through Table 7.

In Table 1, the variables from the National Association of Home Builders' (NAHB) Builder's Survey are shown. For each county these include the name of the TMY2 weather tape[9], the NAHB designation (i.e., east or west Texas designation), the NAHB's window to wall area (as reported by the builders[10]), glazing U-value and SHGC values reported by the builders, as well as roof and wall insulation values. These values are used in the pre-code simulation simulation input.

In Table 2, the variables from the 2000 International Energy Conservation Code (2000 IECC) data are shown. For each county these include the name of the TMY2 weather tape, the NAHB's window to wall area (as reported by the builders[11]), and the glazing U-value and SHGC values from the 2000 IECC for the climate zone associated with each county. The roof and wall U-values represent the maximum value from either the NAHB survey or the 2000 IECC[12]. These values are used in the code-compliant simulation input.

In Table 3 (Single-Family Residential) and Table 4 (Multi-Family Residential), the complete list of DOE-2 inputs are shown, including parameters for DOE-2's LOADS inputs, and SYSTEMS inputs. For each input, the parameter number is listed, a description of the parameter, its default value, status of the variable, and specific comments about the parameter. In the status column, parameters indicated as "user defined" are parameters that can be changed by the user on the web page input to the emissions calculator (Figure 12 and Figure 13).

Once the user submits their analysis to the emissions calculator, it calculates the code-compliant, pre-code, and user simulations. The calculator then extracts specific information from the simulations as shown in Table 5 through Table 7. In Table 5, the DOE-2 Building Energy Performance Summary (BEPS) output is shown from which the building's energy use (Btu) is extracted. In Table 6, the DOE-2 Building Energy Performance Summary Utility Units (BEPU) output is shown from which the building's energy use (kWh, Therms) is extracted. Finally, in Table 7, the DOE-2 Hourly-Report is shown for August 19, 1999, which is used to calculate the peak-day energy and emissions savings.

In the next step of the analysis, the emissions calculator calculates the NOx, SOx and CO_2 using the USEPA's eGRID database. To accomplish this, the electricity use associated with a specific county and Power Control Authority (Table 9) is fed into the eGRID matrix (Table 8). eGRID then proportions the emissions to the power plants according to the actual electricity produced in 1999 for the plants associated with the Power Control Authority (PCA). The PCA assignment to each county was made according to the Texas Public Utility Commission's published power suppliers[13]. These PCA assignments then determine

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[6] These pre-code values use the Builder Survey information collected by the National Association of Home Builders for the State of Texas (NAHB 2000).

[7] The code-compliant values are from the 2000 IECC, as modified by the 2001 Supplement for the climate zone associated with the county in which the project takes place.

[8] See Section 0 for additional information on the 1999 weather data.

[9] The TMY2 weather files were used in the Laboratory's 2002 and 2003 Annual Report. In this report, and in the Emissions Calculator, weather files from data measured in 1999 are used.

[10] This value is calculated from the reported number of windows times the most common type of window installed, as defined by a 2003 phone survey of building suppliers.

[11] The code-compliant simulation using the 2000 IECC uses the same window-to-wall areas as the NAHB data. This is done to normalize the building's window area.

[12] The use the maximum U-value from the NAHB survey or the 2000 IECC prevents the analysis from simulating a code-compliant U-value that is smaller than the NAHB's value.

[13] Obtained from PUCT website: http://www.puc.state.tx.us. November, 2002.

which column is entered in Table 8. In the first column in Table 8, the counties are grouped to the TCEQ's State Implementation Plan (SIP) area. The second column lists the county name. In the third and fourth columns, which are repeated for each PCA, the published NOx emissions (lbs-NOx/MWh) are listed in column 3, which are then shown multiplied by ratio of electricity saved, located at the bottom of the column. In Table 8, emissions are being calculated for Reliant HL&P, in this case 13,370.5 MWh are shown to produce 33,158.84 lbs of NOx, or 16.58 tons/year across 22 counties where HL&P produced emissions in 1999.

These results are then reported by the emissions calculator as shown in Table 10, which is emailed to the user as HTML and XML files. In Table 10, the basic project information is reported at the top of the figure, and includes the project ID[14], user's email address and type of analysis. The emissions calculator then contains a series of reports that show the: 1) total annual energy savings, 2) daily savings on the ozone peak day, for pre-code, code-complaint and user-defined simulations, including energy saved (kWh, or Therms), and 3) 1998 and projected 2007 emissions reductions[15] from eGRID (NOx, SOx and CO_2).

[14] In the future, this project ID will allow a user to run and save the analysis on a database associated with the emissions calculator.
[15] In Table 10 the emissions reductions are shown for 1998 and values projected for 2007. Future versions of the calculator are intended to include 1999 and projected 2007 values.

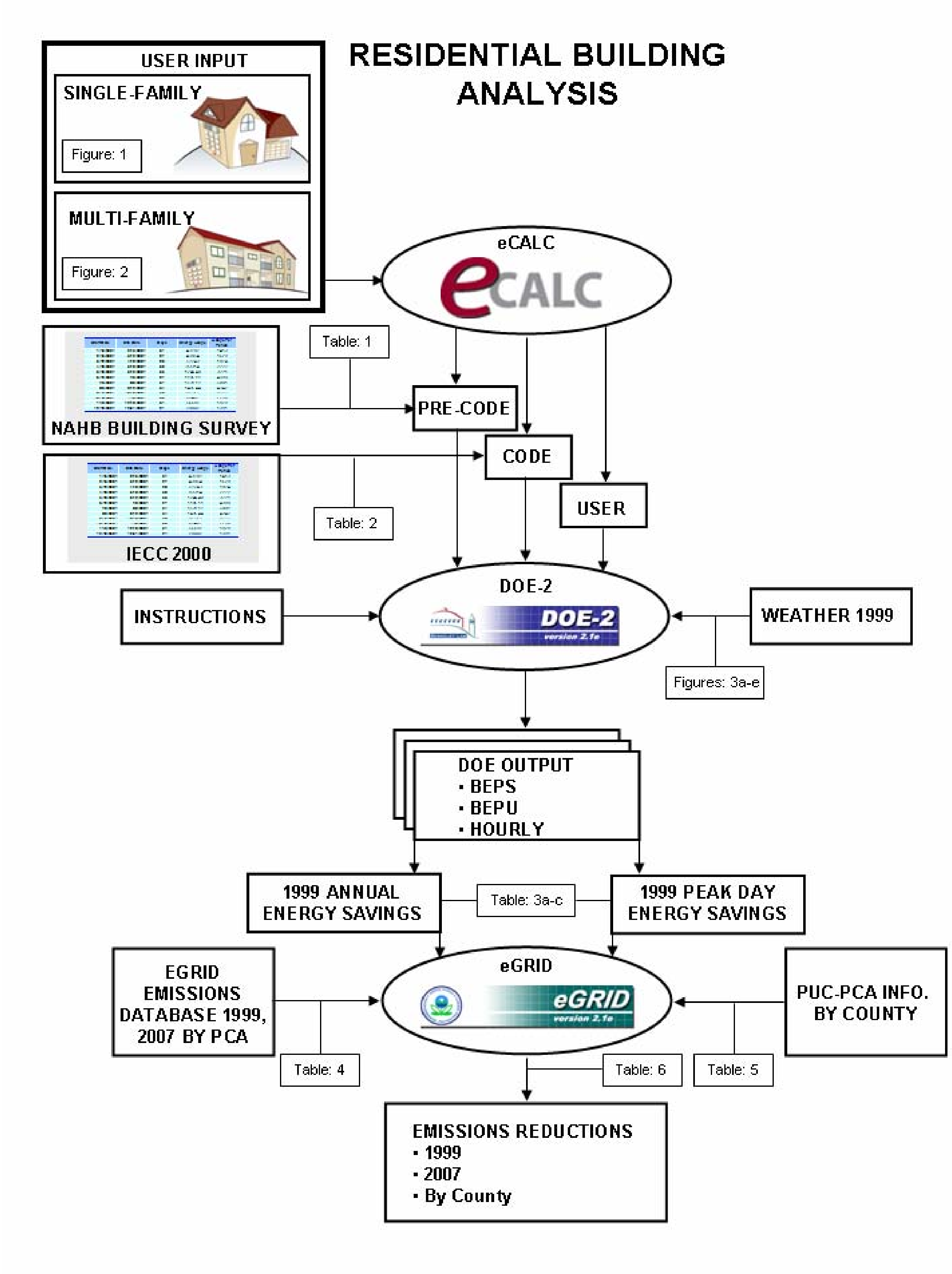

Figure 10: Single- and Multi-family Residence Analysis Flowchart.

	County	TMY2	Division (East or West)	1999 Average				
				Area %	Glazing U-value	SHGC	Roof Insulation	Wall Insulation
Non-attainment	**Brazoria**	Houston	East	13.8	1.11	0.71	27.08	13.99
	Chambers	Port Arthur	East	13.8	1.11	0.71	27.08	13.99
	Collin	Fort Worth	West	20.6	0.87	0.66	26.75	14.18
	Dallas	Fort Worth	West	20.6	0.87	0.66	26.75	14.18
	Denton	Fort Worth	West	20.6	0.87	0.66	26.75	14.18
	El Paso	El Paso	West	20.6	0.87	0.66	26.75	14.18
	Fort Bend	Houston	East	13.8	1.11	0.71	27.08	13.99
	Galveston	Houston	East	13.8	1.11	0.71	27.08	13.99
	Hardin	Port Arthur	East	13.8	1.11	0.71	27.08	13.99
	Harris	Houston	East	13.8	1.11	0.71	27.08	13.99
	Jefferson	Port Arthur	East	13.8	1.11	0.71	27.08	13.99
	Liberty	Port Arthur	East	13.8	1.11	0.71	27.08	13.99
	Montgomery	Houston	East	13.8	1.11	0.71	27.08	13.99
	Orange	Port Arthur	East	13.8	1.11	0.71	27.08	13.99
	Tarrant	Fort Worth	West	20.6	0.87	0.66	26.75	14.18
	Waller	Houston	East	13.8	1.11	0.71	27.08	13.99
Affected	**Bastrop**	Austin	West	20.6	0.87	0.66	26.75	14.18
	Bexar	San Antonio	West	20.6	0.87	0.66	26.75	14.18
	Caldwell	Austin	West	20.6	0.87	0.66	26.75	14.18
	Comal	San Antonio	West	20.6	0.87	0.66	26.75	14.18
	Ellis	Fort Worth	West	20.6	0.87	0.66	26.75	14.18
	Gregg	Lufkin	East	13.8	1.11	0.71	27.08	13.99
	Guadalupe	San Antonio	West	20.6	0.87	0.66	26.75	14.18
	Harrison	Lufkin	East	13.8	1.11	0.71	27.08	13.99
	Hays	Austin	West	20.6	0.87	0.66	26.75	14.18
	Johnson	Fort Worth	West	20.6	0.87	0.66	26.75	14.18
	Kaufman	Fort Worth	West	20.6	0.87	0.66	26.75	14.18
	Nueces	Corpus Christi	East	13.8	1.11	0.71	27.08	14.18
	Parker	Fort Worth	West	20.6	0.87	0.66	26.75	14.18
	Rockwall	Fort Worth	West	20.6	0.87	0.66	26.75	14.18
	Rusk	Lufkin	East	13.8	1.11	0.71	27.08	13.99
	San Patricio	Corpus Christi	East	13.8	1.11	0.71	27.08	14.18
	Smith	Lufkin	East	13.8	1.11	0.71	27.08	13.99
	Travis	Austin	West	20.6	0.87	0.66	26.75	14.18
	Upshur	Lufkin	East	13.8	1.11	0.71	27.08	13.99
	Victoria	Victoria	East	20.6	1.11	0.71	27.08	14.18
	Williamson	Austin	West	13.8	0.87	0.66	26.75	14.18
	Wilson	San Antonio	West	20.6	0.87	0.66	26.75	14.18

Table 1: Single- and Multi-family Residence Analysis Flowchart (Table 1: NAHB Data).

	County	TMY2	2000 IECC				
			Area %	Glazing U-value	SHGC	Roof Insulation	Wall Insulation
Non-attainment	**Brazoria**	Houston	13.8	0.75	0.4	27.08	14.18
	Chambers	Port Arthur	13.8	0.75	0.4	27.08	13.99
	Collin	Fort Worth	20.6	0.46	0.4	38	16
	Dallas	Fort Worth	20.6	0.5	0.4	38	14.18
	Denton	Fort Worth	20.6	0.46	0.4	38	16
	El Paso	El Paso	20.6	0.46	0.4	38	16
	Fort Bend	Houston	13.8	0.75	0.4	27.08	13.99
	Galveston	Houston	13.8	0.75	0.4	27.08	14.18
	Hardin	Port Arthur	13.8	0.75	0.4	27.08	13.99
	Harris	Houston	13.8	0.75	0.4	27.08	13.99
	Jefferson	Port Arthur	13.8	0.75	0.4	27.08	13.99
	Liberty	Port Arthur	13.8	0.75	0.4	27.08	13.99
	Montgomery	Houston	13.8	0.75	0.4	27.08	13.99
	Orange	Port Arthur	13.8	0.75	0.4	27.08	13.99
	Tarrant	Fort Worth	20.6	0.5	0.4	38	14.18
	Waller	Houston	13.8	0.75	0.4	27.08	13.99
Affected	**Bastrop**	Austin	20.6	0.52	0.4	30	14.18
	Bexar	San Antonio	20.6	0.52	0.4	30	14.18
	Caldwell	Austin	20.6	0.52	0.4	30	14.18
	Comal	San Antonio	20.6	0.52	0.4	30	14.18
	Ellis	Fort Worth	20.6	0.5	0.4	38	14.18
	Gregg	Lufkin	13.8	0.6	0.4	30	13.99
	Guadalupe	San Antonio	20.6	0.52	0.4	30	14.18
	Harrison	Lufkin	13.8	0.6	0.4	30	13.99
	Hays	Austin	20.6	0.5	0.4	38	14.18
	Johnson	Fort Worth	20.6	0.5	0.4	38	14.18
	Kaufman	Fort Worth	20.6	0.46	0.4	38	16
	Nueces	Corpus Christi	13.8	0.75	0.4	27.08	14.18
	Parker	Fort Worth	20.6	0.46	0.4	38	16
	Rockwall	Fort Worth	20.6	0.46	0.4	38	16
	Rusk	Lufkin	13.8	0.65	0.4	30	13.99
	San Patricio	Corpus Christi	13.8	0.75	0.4	27.08	14.18
	Smith	Lufkin	13.8	0.65	0.4	30	13.99
	Travis	Austin	20.6	0.5	0.4	38	14.18
	Upshur	Lufkin	13.8	0.6	0.4	30	13.99
	Victoria	Victoria	20.6	0.75	0.4	27.08	14.18
	Williamson	Austin	13.8	0.5	0.4	38	14.18
	Wilson	San Antonio	20.6	0.52	0.4	30	14.18

Table 2: Single- and Multi-family Residence Analysis Flowchart (Table 2: 2000 IECC Data)

PARAMETER NO:	DESCRIPTION	DEFAULT	STATUS	COMMENT
LOADS				
b01	Quick or thermal mode (Q or T)	Quick (Q)	Fixed	Q simulates the building as massless, T will include thermal mass
b02	Location (county name)	Bastrop (BAS)	User Defined	41 counties linked to 9 TRY packed weather files according to climate zone
b03	Azimuth of building (degree)	0	User Defined	Orientation of the building
b04	Width of building (ft)	50	User Defined	
b05	Depth of building (ft)	50	User Defined	
b06	Height of wall (ft)	8	User Defined	
b07	Door height (ft)	6.67	Fixed	Value from survey of manufactured doors
b08	Door width (ft)	3	Fixed	Value from survey of manufactured doors
b09	Run year	2000	User Defined	
b10	Option of second floor (1 or 2)	one floor (1)	User Defined	Controls activation/deactivation of one and two story portions of the BDL input
b11	Activation/ Deactivation of crawl (C or S)	Slab (S)	User Defined	Controls activation/deactivation of crawl space and slab on grade floor types for the residence
b12	Height of crawl space wall above ground(ft)	1.5	User Defined	
b13	Height of crawl space walll under ground(ft)	1	User Defined	
c01	Roof outside emissivity	0.89	User Defined	c01 and c02 are used to define "Roof color"
c02	Roof absorptance	0.45	User Defined	
c03	Roof roughness	1	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c04	Roof R-value (Hr-sq.ft-F/Btu)	R-26	User Defined	
c05	Wall absorptance	0.57	User Defined	c05 and c07 are used to define "wall color"
c06	Wall roughness	2	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c07	Wall outside emissivity	0.9	User Defined	c05 and c07 are used to define "wall color"
c08	Wall R-value (Hr-sq.ft-F/Btu)	R-13	User Defined	
c09	Ground reflectance	0.24	Fixed	This defines the fraction of sunlight reflected from the ground
c10	Window option (S or D)	Same (S)	User Defined	Controls the input of same or different windows on individual orientation of the house
c11	U-Factor of glazing (Btu/hr-sq.ft-F)	0.75	User Defined	
c12	Solar Heat Gain Coefficient(SHGC)	0.4	User Defined	
c13	Number of panes of glazing	2	Fixed	
c14	Frame absorptance of glazing	0.7	Fixed	
c15	Frame type - A,B,C,D,E	Aluminium w/o thermal break (A)	User Defined	Allows user to select from 5 different frame types
c16		Void		
c17	Floor weight (lb/sq-ft)	11.5	Fixed	Value from IECC 2000
c18		Void		
c19	R-value of concrete slab (hr-sq.ft-F/Btu)	0.44	Fixed	
c20	Air film resistance (hr-sq.ft-F/Btu)	0.77	Fixed	
c21	Percentage of window area (%) for whole area or front side wall	15	User Defined	
c22	Percentage of window area (%) for back side wall	15	User Defined	
c23	Percentage of window area (%) for right side wall	15	User Defined	
c24	Percentage of window area (%) for left side wall	15	User Defined	
c25	Percentage of window area (%) for 2nd floor left side wall	15	User Defined	
c26	Floor R-Value (hr-sq.ft-F/Btu)	11	User Defined	
c27	Crawl space wall R-value (hr-sq.ft-F/Btu)	R-5 (F)	User Defined	Allows user to select from 13 different insulations
c28	Slab perimeter R-value and depth	R-0 (A)	User Defined	Allows user to select from 11 different insulation R-values and depths
sp01	Number of people	2	User Defined	
sp02	Number of bedroom	1	User Defined	
s01	Front eave shade (ft)	0	User Defined	
s02	Back eave shade (ft)	0	User Defined	
s03	Left eave shade (ft)	0	User Defined	
s04	Right eave shade (ft)	0	User Defined	
SYSTEM				
sy01	Mode of system: 1, 2, 3	Gas/Electric (1)	User Defined	Allows user to select all-electric, gas/electric or heatpump for HVAC
sy02	Cooling Capacity of cooling system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy03	Heating Capacity of heating system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy04	Seasonal Energy Efficiency Ratio (SEER)	10	User Defined	
sy05	ANNUAL FUEL UTILIZATION EFFICIENCY (AFUE)	0.8	User Defined	
sy06	HEATING SEASONAL PERFORMANCE FACTOR (HSPF)	6.8	User Defined	
sy07	The number of pilot lights of DHW	0	User Defined	
sy08	The number of pilot lights of Furnace	0	User Defined	
sy09	The number of pilot lights of others	0	User Defined	
sy10	Switch for Energy Factor for Domestic Hot Water consumption	Autosized (A)	User Defined	Allows user to input a DHW or let DOE-2 calculate the size and efficiency of the DHW
sy11	Energy Factor (%) for Domestic Hot Water	54	User Defined	Only applicable if the user chooses sy10 = S (EF is user defined)

Table 3: Single- and Multi-family Residence Analysis Flowchart (Complete Listing of Input Parameters for Single-family model).

PARAMETER NO:	DESCRIPTION	DEFAULT	STATUS	COMMENT
LOADS				
b01	Quick or thermal mode (Q or T)	Quick (Q)	Fixed	Q simulates the building as massless, T will include thermal mass
b02	Location	Bastrop (BAS)	User Defined	41 counties linked to 9 TRY packed weather files according to climate zone
b03	Azimuth of building (degree)	0	User Defined	Orientation of the building
b04	Width of unit (ft)	30	User Defined	
b05	Depth of unit (ft)	30	User Defined	
b06	Height of wall (ft)	8	User Defined	
b07	Door height (ft)	6.67	Fixed	Value from survey of manufactured doors
b08	Door width (ft)	3	Fixed	Value from survey of manufactured doors
b09	Run Period	2000	User Defined	
b10	Unit Configuration	1 floor 2 units (A)	User Defined	User can choose from 6 different configurations from 1 floor 2 units to 3 floors 12 units
b11	Activation/ Deactivation of crawl (C or S)	Slab (S)	Fixed	In Multifamily the crawl space is always deactivated
b12	Height of crawl space wall above ground(ft)	1.5	Fixed	Crawl space is deactivated
b13	Height of crawl space walll under ground(ft)	1	Fixed	Crawl space is deactivated
c01	Roof outside emissivity	0.89	User Defined	c01 and c02 are used to define "Roof color"
c02	Roof absorptance	0.45	User Defined	
c03	Roof roughness	1	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c04	Roof R-value (Hr-sq.ft-F/Btu)	R-19	User Defined	
c05	Wall absorptance	0.57	User Defined	c05 and c07 are used to define "wall color"
c06	Wall roughness	2	Fixed	This is used to calculate the outside film
c07	Wall outside emissivity	0.9	User Defined	c05 and c07 are used to define "wall color"
c08	Wall R-value (Hr-sq.ft-F/Btu)	R-11	User Defined	
c09	Ground reflectance	0.24	Fixed	This defines the fraction of sunlight reflected from the ground
c10	Window option (S or D)	Same (S)	User Defined	Controls the input of same or different windows on individual orientation of the house
c11	U-Factor of glazing (Btu/hr-sq.ft-F)	0.85	User Defined	
c12	Solar Heat Gain Coefficient(SHGC)	0.4	User Defined	
c13	Number of pane of glazing	2	Fixed	
c14	Frame absorptance of glazing	0.7	Fixed	
c15	Frame type - A,B,C,D,E	Aluminum w/o thermal break (A)	User Defined	Allows user to select from 5 different frame types
c16	VOID			
c17	Floor weight (lb/sq-ft)	11.5	Fixed	Value from IECC 2000
c18	VOID			
c19	R-value of concrete slab (hr-sq.ft-F/Btu)	0.44	Fixed	
c20	Air film resistance (hr-sq.ft-F/Btu)	0.77	Fixed	
c21	Percentage of window area (%) for front side wall	20	User Defined	
c22	Percentage of window area (%) for back side wall	20	User Defined	
c23	Percentage of window area (%) for right side wall	20	User Defined	
c24	Percentage of window area (%) for left side wall	20	User Defined	
c25	Floor R-Value (hr-sq.ft-F/Btu)	11	User Defined	
c26	Crawl space wall R-value (hr-sq.ft-F/Btu)	R-5 (F)	Fixed	Crawl space is deactivated
c27	Slab perimeter R-value and depth	R-0 (A)	User Defined	Allows user to select from 11 different insulation R-values and depths
sp01	Number of people	2	User Defined	
sp02	Number of bedroom	1	User Defined	
s01	Front eave shade (ft)	0	User Defined	
s02	Back eave shade (ft)	0	User Defined	
s03	Left eave shade (ft)	0	User Defined	
s04	Right eave shade (ft)	0	User Defined	
SYSTEM				
sy01	Mode of system: 1, 2, 3	Gas/electric (1)	User Defined	Allows user to select all-electric, gas/electric or heatpump for HVAC
sy02	Cooling Capacity of cooling system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy03	Heating Capacity of heating system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy04	Seasonal Energy Efficiency Ratio (SEER)	10	User Defined	
sy05	ANNUAL FUEL UTILIZATION EFFICIENCY (AFUE)	0.8	User Defined	
sy06	HEATING SEASONAL PERFORMANCE FACTOR (HSPF)	6.8	User Defined	
sy07	The number of pilot lights of DHW	0	User Defined	
sy08	The number of pilot lights of Furnace	0	User Defined	
sy09	The number of pilot lights of others	0	User Defined	
sy10	Switch for Energy Factor for Domestic Hot Water consumption	Autosized (A)	User Defined	Allows user to input a DHW or let DOE-2 calculate the size and efficiency of the DHW
sy11	Energy Factor (%) for Domestic Hot Water	54	User Defined	Only applicable if the user chooses sy10 = S (EF is user defined)

Table 4: Single- and Multi-family Residence Analysis Flowchart (Complete Listing of Input Parameters for Multi-family model).

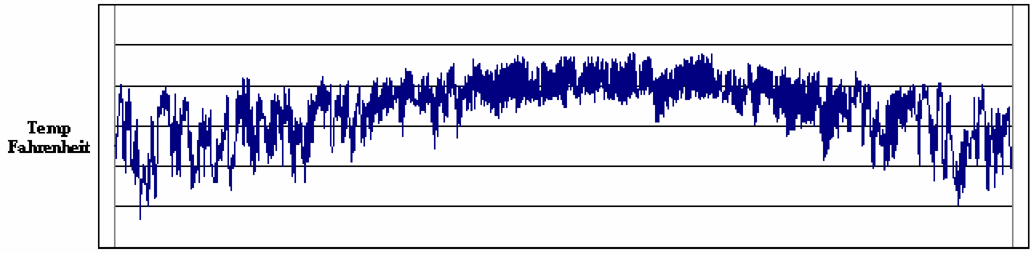

Figure 3a: Hourly data for Dry Bulb Temperature - 1999

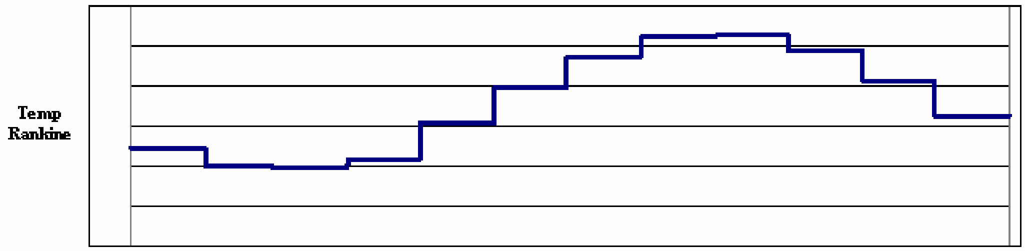

Figure 3b: Hourly data for Ground Temperature - 1999

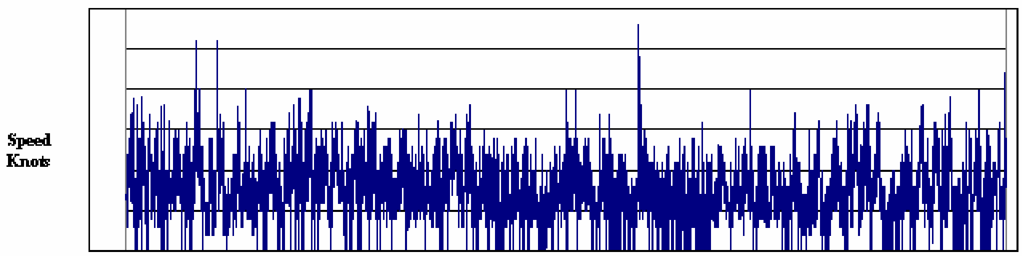

Figure 3c: Hourly data for Wind Speed - 1999

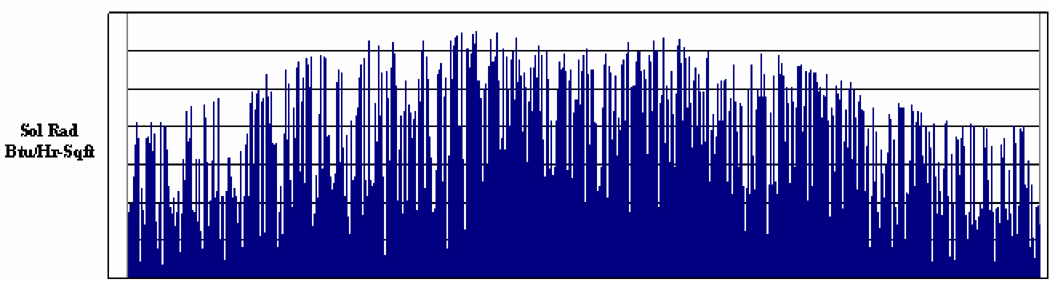

Figure 3d: Hourly data for Global Solar Radiation - 1999

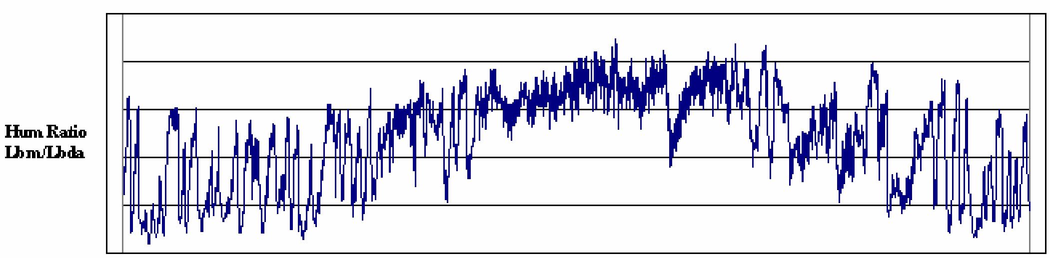

Figure 3e: Hourly data for Humidity Ratio - 1999

Figure 11: Single- and Multi-family Residence Analysis Flowchart (Tables 3a-3e: 1999 Weather Data).

```
1SB5 PROJECT                       RESIDENTIAL PROTOTYPE             DOE-2.1E-119  Fri Oct  8 13:21:56 2004PDL
RUN  1
 PLANTS DESCRIPTION                RESIDENTIAL SYSTEM
 REPORT- BEPS  BUILDING ENERGY PERFORMANCE SUMMARY                              WEATHER FILE- GGG 1999

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                             ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                             UNITS: MBTU

                          CATEGORY OF USE
                          ---------------

                              AREA LIGHTS         13.2          0.0

                             MISC EQUIPMT         13.2          0.0

                               SPACE HEAT          0.0         14.0

                               SPACE COOL          8.9          0.0

                             PUMPS & MISC          0.3          0.0

                                VENT FANS          1.4          0.0

                             DOMHOT WATER          0.0         12.1
                                            ----------   ----------

                                    TOTAL         36.9         26.1


                TOTAL SITE ENERGY        63.01 MBTU     25.2 KBTU/SQFT-YR GROSS-AREA     25.2 KBTU/SQFT-YR NET-AREA
                TOTAL SOURCE ENERGY     136.89 MBTU     54.8 KBTU/SQFT-YR GROSS-AREA     54.8 KBTU/SQFT-YR NET-AREA

                PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE =  0.0
                PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED                =  0.0

                NOTE:  ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.
```

Table 5: Single- and Multi-family Residence Analysis Flowchart (Table 3a: Sample of DOE-2.1e Output for Single-Family Unit – BEPS).

```
1SB5 PROJECT                       RESIDENTIAL PROTOTYPE             DOE-2.1E-119  Fri Oct  8 13:21:56 2004PDL
RUN  1
 PLANTS DESCRIPTION                RESIDENTIAL SYSTEM
 REPORT- BEPU  BUILDING ENERGY PERFORMANCE SUMMARY (UTILITY UNITS)              WEATHER FILE- GGG 1999

------------------------------------------------------------------------------------------------------------------------------
------


                             ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                              SITE UNITS:       KWH          THERM

                          CATEGORY OF USE
                          ---------------

                              AREA LIGHTS        3854.            0.

                             MISC EQUIPMT        3854.            0.

                               SPACE HEAT           0.          140.

                               SPACE COOL        2617.            0.

                             PUMPS & MISC          79.            0.

                                VENT FANS         417.            0.

                             DOMHOT WATER           0.          121.
                                            ----------   ----------

                                    TOTAL       10821.          261.


        TOTAL ELECTRICITY     10821. KWH        4.328 KWH    /SQFT-YR GROSS-AREA    4.328 KWH     /SQFT-YR NET-AREA
        TOTAL NATURAL-GAS       261. THERM      0.104 THERM  /SQFT-YR GROSS-AREA    0.104 THERM   /SQFT-YR NET-AREA

                PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE =  0.0
                PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED                =  0.0

                NOTE:  ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.
```

Table 6: Single- and Multi-family Residence Analysis Flowchart (Table 3b: Sample of DOE-2.1e Output for Single-Family Unit – BEPU).

```
1SB5 PROJECT                            RESIDENTIAL PROTOTYPE                   DOE-2.1E-119  Fri Oct  8 13:21:56 2004SDL
RUN  1
 SYSTEM DESCRIPTION                     RESIDENTIAL SYSTEM
 REP1            = HOURLY-REPORT
PAGE231 -  1

-------------------------------------------------------------------------------------------------------------------------
------
         GLOBAL      END-USE      END-USE

         DRY BULB    HEATING      DHW HEAT
         TEMP        FUEL PA1     FUEL PA1
         F           BTU/HR       BTU/HR

         ----( 8)    ----(15)     ----(18)
  819 1      81.0         0.000     1135.721
  819 2      80.0         0.000     1135.721
  819 3      77.0         0.000     1135.721
  819 4      79.0         0.000     1135.721
  819 5      75.0         0.000     1135.721
  819 6      75.0         0.000     1135.721
  819 7      80.0         0.000     1135.721
  819 8      84.0         0.000     1135.721
  819 9      90.0         0.000     1135.721
  81910      94.0         0.000     1135.721
  81911      97.0         0.000     1135.721
  81912      98.0         0.000     1135.721
  81913     103.0         0.000     1135.721
  81914     104.0         0.000     1135.721
  81915     103.0         0.000     1135.721
  81916     102.0         0.000     1135.721
  81917     102.0         0.000     1135.721
  81918     100.0         0.000     1135.721
  81919      93.0         0.000     1135.721
  81920      85.0         0.000     1135.721
  81921      87.0         0.000     1135.721
  81922      83.0         0.000     1135.721
  81923      80.0         0.000     1135.721
  81924      80.0         0.000     1135.721
0 DAILY SUMMARY (AUG 19)
     MN      75.0         0.000     1135.721
     MX     104.0         0.000     1135.721
     SM    2132.0         0.000    27257.299
     AV      88.8         0.000     1135.721
```

Table 7: Single- and Multi-family Residence Analysis Flowchart (Table 3c: Sample of DOE-2.1e Output – Hourly report August 19, 1999).

Area	County	American Electric Power - West (ERCOT) /PCA	NOx Reductions (lbs)	Austin Energy/PCA	NOx Reductions (lbs)	Brownsville Public Utils Board/PCA	NOx Reductions (lbs/year)	Lower Colorado River Autohrity /PCA	NOx Reductions (lbs)	Reliant Energy HL&P/PCA	NOx Reductions (lbs)	San Antonio Public Service Bd/PCA	NOx Reductions (lbs)	South Texas Electric Coop INC/PCA	NOx Reductions (lbs)	Texas Municipal Power Pool/PCA	NOx Reductions (lbs)	Texas-New Mexico Power Co/PCA	NOx Reductions (lbs)	TXU Electric/PCA	NOx Reductions (lbs)	Total Nox Reductions (lbs)	Total Nox Reductions (Tons)
Austin-San Antonio Area	BASTROP	0.01	0.00	0.20	0.00		0.00	0.34	0.00		0.00	0.01	0.00		0.00		0.00		0.00		0.00	0.00	0.00
	BEXAR	0.06	0.00	0.09	0.00	0.04	0.00	0.16	0.00		0.00	2.00	0.00	0.08	0.00	0.01	0.00		0.00		0.00	0.00	0.00
	TRAVIS		0.00	0.46	0.00		0.00	0.05	0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	FAYETTE	0.02	0.00	0.86	0.00	0.02	0.00	1.51	0.00	0.01	133.71	0.04	0.00	0.01	0.00	0.02	0.00		0.00	0.02	0.00	133.71	0.07
	LLANO		0.00	0.12	0.00		0.00	0.21	0.00		0.00	0.01	0.00		0.00		0.00		0.00		0.00	0.00	0.00
	CALDWELL		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	COMAL		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	GUADALUPE		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	HAYS		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	WILLIAMSON		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	WILSON		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
Dallas-Fort Worth Area	COLLIN	0.01	0.00	0.01	0.00		0.00	0.02	0.00	0.01	133.71		0.00	0.05	0.00	0.19	0.00		0.00	0.02	0.00	133.71	0.07
	DALLAS	0.06	0.00	0.06	0.00	0.04	0.00	0.09	0.00	0.03	401.12	0.01	0.00	0.09	0.00	0.30	0.00	0.09	0.00	0.51	0.00	401.12	0.20
	DENTON		0.00	0.01	0.00		0.00	0.01	0.00		0.00		0.00	0.04	0.00	0.15	0.00		0.00	0.01	0.00	0.00	0.00
	JOHNSON		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.01	0.00		0.00		0.00	0.00	0.00
	PARKER		0.00		0.00		0.00		0.00		0.00		0.00	0.01	0.00	0.03	0.00		0.00		0.00	0.00	0.00
	CHEROKEE	0.01	0.00	0.01	0.00	0.01	0.00	0.02	0.00		0.00		0.00	0.02	0.00	0.06	0.00	0.02	0.00	0.10	0.00	0.00	0.00
	COKE	0.03	0.00		0.00	0.02	0.00		0.00		0.00		0.00	0.01	0.00		0.00		0.00		0.00	0.00	0.00
	COLEMAN	0.02	0.00		0.00	0.01	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	FANNIN	0.02	0.00	0.02	0.00	0.01	0.00	0.03	0.00	0.01	133.71		0.00	0.03	0.00	0.09	0.00	0.03	0.00	0.17	0.00	133.71	0.07
	FRIO	0.05	0.00		0.00	0.04	0.00	0.01	0.00		0.00		0.00	1.15	0.00	0.07	0.00		0.00		0.00	0.00	0.00
	HARDEMAN	0.01	0.00		0.00	0.01	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	HASKELL	0.16	0.00		0.00	0.12	0.00	0.01	0.00		0.00		0.00	0.03	0.00	0.01	0.00		0.00	0.01	0.00	0.00	0.00
	HENDERSON		0.00		0.00		0.00	0.01	0.00		0.00		0.00		0.00	0.02	0.00	0.01	0.00	0.03	0.00	0.00	0.00
	HOOD	0.02	0.00	0.02	0.00	0.02	0.00	0.04	0.00	0.01	133.71		0.00	0.03	0.00	0.12	0.00	0.04	0.00	0.22	0.00	133.71	0.07
	JONES	0.14	0.00		0.00	0.11	0.00		0.00		0.00		0.00	0.03	0.00		0.00		0.00	0.01	0.00	0.00	0.00
	LAMAR		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.01	0.00	0.00	0.00
	LIMESTONE	0.01	0.00	0.01	0.00		0.00		0.00	0.05	668.53	0.01	0.00		0.00		0.00		0.00		0.00	668.53	0.33
	MCLENNAN	0.04	0.00	0.04	0.00	0.03	0.00	0.07	0.00	0.02	267.41	0.01	0.00	0.06	0.00	0.22	0.00	0.07	0.00	0.40	0.00	267.41	0.13
	MITCHELL	0.04	0.00	0.04	0.00	0.03	0.00	0.07	0.00	0.02	267.41	0.01	0.00	0.06	0.00	0.21	0.00	0.07	0.00	0.39	0.00	267.41	0.13
	NOLAN		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.01	0.00	0.00	0.00
	PALO PINTO	0.01	0.00	0.02	0.00	0.01	0.00	0.03	0.00	0.01	133.71		0.00	0.09	0.00	0.36	0.00		0.00	0.02	0.00	133.71	0.07
	RED RIVER		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.01	0.00		0.00	0.02	0.00	0.00	0.00
	TAYLOR	0.01	0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	TITUS	0.01	0.00	0.01	0.00	0.01	0.00	0.02	0.00		0.00		0.00	0.02	0.00	0.05	0.00	0.02	0.00	0.10	0.00	0.00	0.00
	YOUNG	0.02	0.00	0.02	0.00	0.01	0.00	0.03	0.00	0.01	133.71		0.00	0.03	0.00	0.09	0.00	0.03	0.00	0.16	0.00	133.71	0.07
	TARRANT	0.04	0.00	0.04	0.00	0.03	0.00	0.06	0.00	0.02	267.41	0.01	0.00	0.05	0.00	0.18	0.00	0.06	0.00	0.33	0.00	267.41	0.13
	ELLIS		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	KAUFMAN		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	ROCKWALL		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
Houston - Galveston Area	BRAZORIA	0.01	0.00	0.01	0.00		0.00		0.00	0.05	668.53	0.01	0.00		0.00		0.00		0.00		0.00	668.53	0.33
	BRAZOS		0.00	0.01	0.00		0.00	0.01	0.00		0.00		0.00	0.03	0.00	0.11	0.00		0.00	0.01	0.00	0.00	0.00
	GRIMES	0.01	0.00	0.01	0.00		0.00	0.02	0.00	0.01	133.71		0.00	0.06	0.00	0.23	0.00		0.00	0.01	0.00	133.71	0.07
	WHARTON		0.00		0.00		0.00		0.00	0.01	133.71		0.00		0.00		0.00		0.00		0.00	133.71	0.07
	CHAMBERS	0.05	0.00	0.06	0.00	0.03	0.00	0.02	0.00	0.36	4679.68	0.08	0.00	0.03	0.00	0.02	0.00	0.02	0.00	0.03	0.00	4679.68	2.34
	FORT BEND	0.13	0.00	0.17	0.00	0.10	0.00	0.06	0.00	1.01	13504.21	0.23	0.00	0.09	0.00	0.06	0.00	0.07	0.00	0.10	0.00	13504.21	6.75
	GALVESTON	0.05	0.00	0.06	0.00	0.04	0.00	0.02	0.00	0.39	5214.50	0.09	0.00	0.04	0.00	0.03	0.00	0.42	0.00	0.04	0.00	5214.50	2.61
	ROBERTSON		0.00		0.00		0.00		0.00	0.01	133.71		0.00		0.00		0.00	0.40	0.00	0.01	0.00	133.71	0.07
	HARRIS	0.05	0.00	0.07	0.00	0.04	0.00	0.02	0.00	0.41	5481.91	0.09	0.00	0.04	0.00	0.02	0.00	0.03	0.00	0.04	0.00	5481.91	2.74
	HARDIN		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	JEFFERSON		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	LIBERTY		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	MONTGOMERY		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	ORANGE		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	WALLER		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
El Paso Area	EL PASO		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
Other	RUSK	0.01	0.00	0.01	0.00	0.01	0.00	0.01	0.00		0.00		0.00	0.01	0.00	0.04	0.00	0.01	0.00	0.07	0.00	0.00	0.00
	CROCKETT	0.14	0.00		0.00	0.11	0.00		0.00		0.00		0.00	0.03	0.00		0.00		0.00	0.01	0.00	0.00	0.00
	FREESTONE	0.02	0.00	0.02	0.00	0.02	0.00	0.04	0.00	0.01	133.71		0.00	0.03	0.00	0.12	0.00	0.04	0.00	0.22	0.00	133.71	0.07
	CALHOUN	0.19	0.00		0.00	0.14	0.00	0.01	0.00		0.00		0.00	0.04	0.00	0.01	0.00		0.00	0.01	0.00	0.00	0.00
	HIDALGO	0.13	0.00		0.00	0.10	0.00		0.00		0.00		0.00	0.03	0.00		0.00		0.00		0.00	0.00	0.00
	CAMERON	0.14	0.00		0.00	0.20	0.00		0.00		0.00		0.00	0.03	0.00		0.00		0.00	0.01	0.00	0.00	0.00
	WARD	0.06	0.00	0.06	0.00	0.04	0.00	0.09	0.00	0.02	267.41	0.01	0.00	0.08	0.00	0.28	0.00	0.10	0.00	0.51	0.00	267.41	0.13
	WEBB	0.06	0.00		0.00	0.05	0.00		0.00		0.00		0.00	0.01	0.00		0.00		0.00		0.00	0.00	0.00
	NUECES	0.74	0.00	0.01	0.00	0.55	0.00	0.02	0.00	0.01	133.71	0.01	0.00	0.15	0.00	0.02	0.00	0.01	0.00	0.03	0.00	133.71	0.07
	VICTORIA	0.30	0.00	0.01	0.00	0.22	0.00	0.01	0.00		0.00		0.00	0.68	0.00	0.05	0.00		0.00	0.01	0.00	0.00	0.00
	GREGG		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	HARRISON		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	SMITH		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	UPSHUR		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	SAN PATRICIO		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00		0.00	0.00	0.00
	TOTAL	**2.89**		**2.54**		**2.22**		**3.12**		**2.48**		**2.63**		**3.27**		**3.19**		**1.54**		**3.65**		33158.84	16.58
Energy Savings by PCA from ESL (MWh)		0.00		0.00		0.00		0.00		13370.50		0.00		0.00		0.00		0.00		0.00			

Table 8: Single- and Multi-family Residence Analysis Flowchart (Table 4: eGRID emissions database).

County	Region Number	Region Name	Electric Utilities							
ANDERSON	6	East Texas Council of Governments	ONCOR	Trinity Valley EC	Houston County EC					
ANDREWS	9	Permian Basin Regional Planning Commission	ONCOR	Cap Rock EC						
ANGELINA	14	Deep East Texas Council of Governments	ONCOR	Sam Houston EC	Houston County EC	Jasper-Newton EC				
ARANSAS	20	Coastal Bend Council of Governments	CPL(AEP)	San Patricio EC						
ARCHER	3	North Texas Regional Planning Commission	ONCOR	T-NMP	J-A-C EC	Fort Belknap EC	Tri-County EC	Southwest Rural EC		
ARMSTRONG	1	Panhandle Regional Planning Commission	XCEL(SPS)	Greenbelt EC	Swisher EC					
ATASCOSA	18	Alamo Area Council of Governments	CPL(AEP)	CPSB	Medina EC	Karnes EC				
AUSTIN	16	Houston-Galvetson Area Council	RELIANT(CENTER POINT)	Bellville	San Benard EC	Bluebonnet EC	Fayette EC			
BAILEY	2	South Plains Association of Governments	XCEL(SPS)	Baliey County EC	Lamb County EC					
BANDERA	18	Alamo Area Council of Governments	Bandera EC							
BASTROP	12	Capitol Area Planning Council	ONCOR	Smithville	Bluebonnet EC	Fayette EC				
BAYLOR	3	North Texas Regional Planning Commission	ONCOR	Seymour	Tri-County EC	Southwest Rural EC				
BEE	20	Coastal Bend Council of Governments	CPL(AEP)	San Patricio EC	Karnes EC					
BELL	23	Central Texas Council of Governments	ONCOR	Bartlett EC	Belfalls EC	McLennan County EC	Pedernales EC	Bartlett		
BEXAR	18	Alamo Area Council of Governments	CPSB	Bandera EC	Karnes EC					
BLANCO	12	Capitol Area Planning Council	Pedernales EC	Central Texas EC						
BORDEN	9	Permian Basin Regional Planning Commission	Lyntegar EC	Big Country EC	Cap Rock EC					
BOSQUE	11	Heart of Texas Council of Governments	T-NMP	United Coop Services	McLennan County EC					
BOWIE	5	Ark-Tex Council of Governments	SWEPCO(AEP)	Bowie-Cass EC	Southwest Arkansas EC					
BRAZORIA	16	Houston-Galveston Area Council	RELIANT(CENTER POINT)	T-NMP	Jackson EC					
BRAZOS	13	Brazos Valley Council of Governments	BRYAN	College Station	Mid-South EC	Navasota Valley EC				
BREWSTER	8	Rio Grande Council of Governments	WTU(AEP)	Rio Grande EC						
BRISCOE	1	Panhandle Regional Planning Commission	XCEL(SPS)	WTU(AEP)	Lighthouse EC	Swisher EC				
BROOKS	20	Coastal Bend Council of Governments	CPL(AEP)	Medina EC	Nueces EC					
BROWN	7	West Central Texas Council of Governments	ONCOR	WTU(AEP)	Cap Rock EC	Comanche EC				
BURLESON	13	Brazos Valley Council of Governments	ENTERGY	BRYAN	Bartlett EC	Bluebonnet EC				
BURNET	12	Capitol Area Planning Council	ONCOR	Pedernales EC						
CALDWELL	12	Capitol Area Planning Council	CPL(AEP)	Luling	Pedernales EC	Bluebonnet EC				
CALHOUN	17	Golden Crescent Regional Planning Commission	CPL(AEP)	Victoria EC	Jackson EC					
CALLAHAN	7	West Central Texas Council of Governments	WTU(AEP)	Taylor EC	Comanche EC					
CAMERON	21	Lower Rio Grande Valley Development Council	CPL(AEP)	Magic Valley EC	Brownsville					
CAMP	6	East Texas Council of Governments	SWEPCO(AEP)	Wood County EC	Upshur-Rural EC					
CARSON	1	Panhandle Regional Planning Commission	XCEL(SPS)							
CASS	5	Ark-Tex Council of Governments	SWEPCO(AEP)	Upshur-Rural EC	Bowie-Cass EC					
CASTRO	1	Panhandle Regional Planning Commission	XCEL(SPS)	Deaf Smith EC	Bailey County EC	Lamb County EC	Swisher EC			
CHAMBERS	16	Houston-Galveston Area Council	RELIANT(CENTER POINT)	ENTERGY						
CHEROKEE	6	East Texas Council of Governments	ONCOR	Cherokee County EC	Houston County EC					
CHILDRESS	1	Panhandle Regional Planning Commission	WTU(AEP)	Greenbelt EC	Lighthouse EC	South Plains EC	Harmon EC			
CLAY	3	North Texas Regional Planning Commission	ONCOR	T-NMP	J-A-C EC	Wise EC				
COCHRAN	2	South Plains Association of Governments	XCEL(SPS)	Baliey County EC	Lamb County EC	Lea County Ec				
COKE	10	Concho Valley Council of Governments	WTU(AEP)	Concho Valley EC	Taylor EC					
COLEMAN	7	West Central Texas Council of Governments	WTU(AEP)	Coleman	Cap Rock EC	Coleman County EC				
COLLIN	4	North Central Texas Council of Governments	ONCOR	T-NMP	Farmersville	Cap Rock EC	Grayson-Collin EC	CoServ E	FEC Electric	Fannin County EC
COLLINGSWORTH	1	Panhandle Regional Planning Commission	WTU(AEP)	Greenbelt EC						
COLORADO	16	Houston-Galveston Area Council	CPL(AEP)	Weimar	Fayette EC	Bluebonnet EC	San Benard EC	Wharton County EC		
COMAL	18	Alamo Area Council of Governments	CPSB	New Braunfels	Pedernales EC					
COMANCHE	7	West Central Texas Council of Governments	ONCOR	T-NMP	Comanche EC	United Coop Services				
CONCHO	10	Concho Valley Council of Governments	WTU(AEP)	Concho Valley EC	Cap Rock EC	Coleman County EC	Southwest Tx EC			
COOKE	22	Texoma Council of Governments	ONCOR	Cooke County EC	CoServ E	Wise EC				
CORYELL	23	Central Texas Council of Governments	ONCOR	T-NMP	McLennan County EC	Hamilton County EC	United Coop Services			
COTTLE	3	North Texas Regional Planning Commission	WTU(AEP)	South Plains EC						
CRANE	9	Permian Basin Regional Planning Commission	ONCOR							
CROCKETT	10	Concho Valley Council of Governments	WTU(AEP)	Rio Grande EC	Southwest Tx EC					
CROSBY	2	South Plains Association of Governments	XCEL(SPS)	Crosbyton	Lighthouse EC	South Plains EC				
CULBERSON	8	Rio Grande Council of Governments	EPEC	Rio Grande EC						
DALLAM	1	Panhandle Regional Planning Commission	XCEL(SPS)	Rita Blanca EC						
DALLAS	4	North Central Texas Council of Governments	ONCOR	Garland	FEC Electric	HILCO EC	Trinity Valley EC			
DAWSON	9	Permian Basin Regional Planning Commission	ONCOR	Lyntegar EC	Cap Rock EC					
DEAF SMITH	1	Panhandle Regional Planning Commission	XCEL(SPS)	Deaf Smith EC	Farmers EC New Mexico					
DELTA	5	Ark-Tex Council of Governments	ONCOR	Lamar County EC	FEC Electric					
DENTON	4	North Central Texas Council of Governments	ONCOR	T-NMP	Denton	Sanger	Cooke County EC	CoServ E	Wise EC	Tri-County EC
DEWITT	17	Golden Crescent Regional Planning Commission	CPL(AEP)	Yoakum	Cuero	DeWitt EC	Victoria EC	South Texas EC		
DICKENS	2	South Plains Association of Governments	WTU(AEP)	South Plains EC	Lighthouse EC					
DIMMIT	24	Middle Rio Grande Development Council	CPL(AEP)	Medina EC	Rio Grande EC					
DONLEY	1	Panhandle Regional Planning Commission	WTU(AEP)	Greenbelt EC	Lighthouse EC					
DUVAL	20	Coastal Bend Council of Governments	CPL(AEP)	Medina EC	Nueces EC	South Texas EC				
EASTLAND	7	West Central Texas Council of Governments	ONCOR	WTU(AEP)	Comanche EC	United Coop Services	Taylor EC			
ECTOR	9	Permian Basin Regional Planning Commission	ONCOR	Goldsmith	Cap Rock EC					
EDWARDS	24	Middle Rio Grande Development Council	CPL(AEP)	Rio Grande EC	Medina EC	Pedernales EC	Southwest Tx EC			
EL PASO	8	Rio Grande Council of Governments	EPEC	Rio Grande EC						
ELLIS	4	North Central Texas Council of Governments	ONCOR	Navarro County EC	HILCO EC	United Coop Services				
ERATH	4	North Central Texas Council of Governments	ONCOR	T-NMP	United Coop Services					
FALLS	11	Heart of Texas Council of Governments	ONCOR	Belfalls EC	McLennan County EC	Navasota Valley EC				
FANNIN	22	Texoma Council of Governments	ONCOR	T-NMP	Fannin County EC	Cap Rock EC	FEC Electric	Lamar County EC		
FAYETTE	12	Capital Area Planning Council	La Grange	Schulenburg	Flatonia	Fayette EC	Bluebonnet EC			
FISHER	7	West Central Texas Council of Governments	WTU(AEP)	Big Country EC	Cap Rock EC	Taylor EC				
FLOYD	2	South Plains Association of Governments	XCEL(SPS)	Floydada	Lighthouse EC	South Plains EC				
FOARD	3	North Texas Regional Planning Commission	WTU(AEP)	Southwest Rural EC	South Plains EC	Tri-County EC				
FORT BEND	16	Houston-Galveston Area Council	RELIANT(CENTER POINT)							
FRANKLIN	5	Ark-Tex Council of Governments	SWEPCO(AEP)	FEC Electric	Bowie-Cass EC	Wood County EC				
FREESTONE	11	Heart of Texas Council of Governments	ONCOR	Navasota Valley EC	Navarro County EC	Houston County EC				
FRIO	18	Alamo Area Council of Governments	CPL(AEP)	Medina EC						
GAINES	9	Permian Basin Regional Planning Commission	XCEL(SPS)	Lyntegar EC	Lea County Ec					
GALVESTON	16	Houston-Galveston Area Council	RELIANT(CENTER POINT)	T-NMP	ENTERGY					
GARZA	2	South Plains Association of Governments	XCEL(SPS)	Big Country EC	Lyntegar EC	South Plains EC				
GILLESPIE	18	Alamo Area Council of Governments	Fredericksburg	Pedernales EC	Central Texas EC					
GLASSCOCK	9	Permian Basin Regional Planning Commission	ONCOR	Cap Rock EC						
GOLIAD	17	Golden Crescent Regional Planning Commission	CPL(AEP)	Karnes EC	Victoria EC	San Patricio EC	DeWitt EC			
GONZALES	17	Golden Crescent Regional Planning Commission	CPL(AEP)	Gonzales	Waelder	Guadalupe Valey EC				
GRAY	1	Panhandle Regional Planning Commission	XCEL(SPS)	Greenbelt EC						
GRAYSON	22	Texoma Council of Governments	ONCOR	T-NMP	Whitesboro	Grayson-Collin EC	Fannin County EC	Cooke County EC	CoServ E	
GREGG	6	East Texas Council of Governments	SWEPCO(AEP)	Rusk County EC	Upshur-Rural EC					
GRIMES	13	Brazos Valley Council of Governments	ENTERGY	Mid-South EC	San Benard EC					
GUADALUPE	18	Alamo Area Council of Governments	CPSB	Seguin	Guadalupe Valey EC	Bluebonnet EC	Pedernales EC			
HALE	2	South Plains Association of Governments	XCEL(SPS)	Swisher EC	Lamb County EC	Lighthouse EC	South Plains EC			
HALL	1	Panhandle Regional Planning Commission	WTU(AEP)	Lighthouse EC	South Plains EC					
HAMILTON	23	Central Texas Council of Governments	T-NMP	United Coop Services	Hamilton County EC	McLennan County EC				
HANSFORD	1	Panhandle Regional Planning Commission	XCEL(SPS)	T-NMP	North Plains EC	Rita Blanca EC				
HARDEMAN	3	North Texas Regional Planning Commission	WTU(AEP)	South Plains EC	Southwest Rural EC	Harmon EC				
HARDIN	15	South East Texas Regional Planning Commission	ENTERGY	RELIANT(CENTER POINT)	Sam Houston EC					
HARRIS	16	Houston-Galveston Area Council	RELIANT(CENTER POINT)	ENTERGY	San Benard EC					
HARRISON	6	East Texas Council of Governments	SWEPCO(AEP)	Panola-Harrison EC	Upshur-Rural EC					
HARTLEY	1	Panhandle Regional Planning Commission	XCEL(SPS)	Rita Blanca EC						
HASKELL	7	West Central Texas Council of Governments	WTU(AEP)	Big Country EC	Tri-County EC					
HAYS	12	Capitol Area Planning Council	San Marcos	Pedernales EC	Bluebonnet EC					
HEMPHILL	1	Panhandle Regional Planning Commission	Canadian	North Plains EC	Greenbelt EC					
HENDERSON	6	East Texas Council of Governments	ONCOR	Trinity Valley EC						
HIDALGO	21	Lower Rio Grande Valley Development Council	CPL(AEP)	Magic Valley EC						
HILL	11	Heart of Texas Council of Governments	ONCOR	T-NMP	HILCO EC	Navasota Valley EC	Navarro County EC			
HOCKLEY	2	South Plains Association of Governments	XCEL(SPS)	South Plains EC	Lyntegar EC	Lamb County EC				
HOOD	4	North Central Texas Council of Governments	ONCOR	T-NMP	Granbury	United Coop Services	Tri-County EC			
HOPKINS	5	Ark-Tex Council of Governments	ONCOR	SWEPCO(AEP)	FEC Electric	Wood County EC				
HOUSTON	14	Deep East Texas Council of Governments	ONCOR	Houston County EC						
HOWARD	9	Permian Basin Regional Planning Commission	ONCOR	Cap Rock EC						
HUDSPETH	8	Rio Grande Council of Governments	EPEC	Rio Grande EC						
HUNT	4	North Central Texas Council of Governments	ONCOR	T-NMP	Greenville	FEC Electric	Cap Rock EC	Trinity Valley EC	Fannin EC	
HUTCHINSON	1	Panhandle Regional Planning Committee	XCEL(SPS)	North Plains EC	Rita Blanca EC					
IRION	10	Concho Valley Council of Governments	WTU(AEP)	Cap Rock EC	Concho Valley EC	Southwest Texas EC				
JACK	3	North Central Texas Council of Governments	ONCOR	T-NMP	J-A-C EC	Tri-County EC	Fort Belknap EC	Wise EC		

Table 9: Single- and Multi-family Residence Analysis Flowchart (Table 5: PUC-PCA Info. by County).

Report on Project 1343: SB5, GREGG

Project Information

Project ID	1343
Job ID	1006
County	GREGG
Project Name	SB5
Project POC EMail	User name@domain.com
Project Type	Single Family

1: ANNUAL Energy Savings

1.1: ANNUAL Energy Consumption

Consumption	Electricity (kWh)	Natural Gas (MMBtu)
PreCode	11,889	26
Code	11,261	23
User Input	10,821	26

1.2: ANNUAL Savings - Energy

Comparison	Electricity (kWh)#	Natural Gas (MMBtu)#
Code vs PreCode	628	3
Code vs User Input	440	-3
User vs PreCode	-1,068	0

1.3: ANNUAL Emissions

1998

Comparison	Emissions (in lbs)#		
	NOx	SOx	CO2
Precode	2.40	0.02	3,069.93
Code	2.12	0.01	2,705.30
User Input	2.40	0.02	3,069.93

2007

Comparison	Emissions (in lbs)#		
	NOx	SOx	CO2
Precode	2.40	0.02	3,069.93
Code	2.12	0.01	2,705.30
User Input	2.40	0.02	3,069.93

Table 10: Single- and Multi-family Residence Analysis Flowchart (Table 6: Web based output for Emissions Reductions).

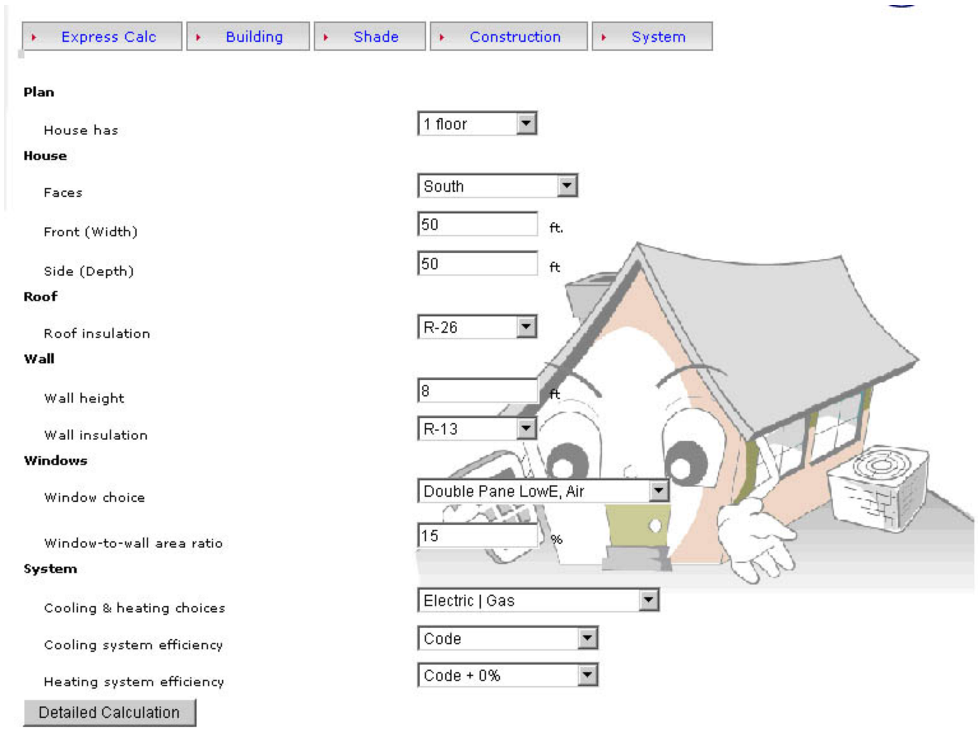


Figure 12: Single- and Multi-family Residence Analysis Flowchart (Figure 1: Excerpt from web- based user interface for Single Family Residence).

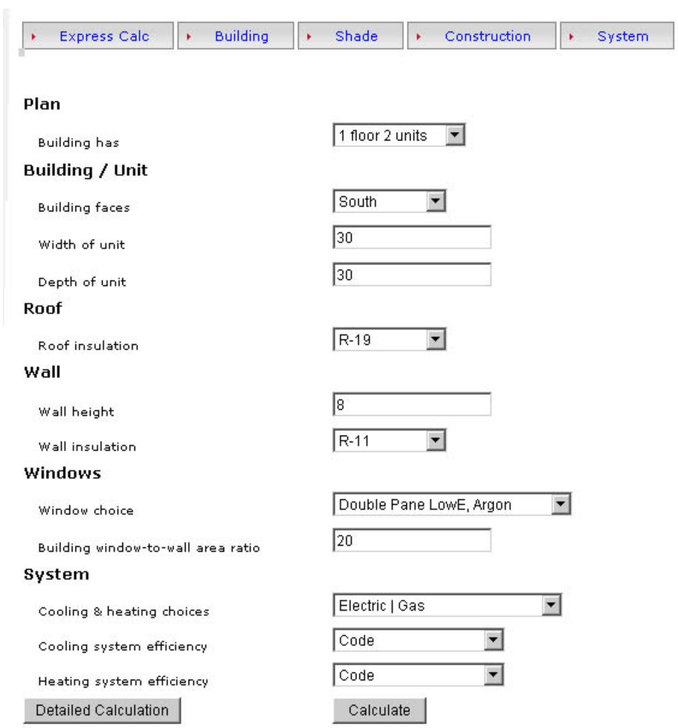


Figure 13: Single- and Multi-family Residence Analysis Flowchart (Figure 1: Excerpt from web-based user interface for Multi-Family Residence).

2.2.3 Commercial Buildings

2.2.3.1 Office Building User Input

The user input screens for the office building model can be seen in Figure 14 through Figure 20. In Figure 14, the user is directed to input their project information, including an email address that will receive the analysis results from the calculator. The user also must provide the county in which the project is located. This information is used to configure the default Power Control Authority (PCA), or Power Provider, which is shown as the next input. In this input the user can select from one or more PCAs that provide power to that county, according to the county-PCA matrix provided by the Texas Public Utilities Commission. The user can also provide information about the available utilities, which is intended to be used in the residential retrofit analysis.

Once the user has provided the information requested in Figure 14, the user is automatically directed to Figure 15, the express entry screen for office buildings. In Figure 15, the required DOE-2 inputs (Table 13 and Table 14) have been reduced to fourteen entries that are required for an express analysis, including information about the building, the roof, the walls, the windows, and the HVAC system. If the user desires additional details about the input parameters, they can switch to the detailed calculation, which takes them to the input screens shown in Figure 16 to Figure 20. In Figure 16, additional building inputs are allowed for the area per person, the lighting load, and the equipment load, the number of floors, azimuth of the building, building width and length, floor-to-floor height, floor-to-ceiling height, and whether or not the building has floors underground.

In Figure 17, the user can enter information about the building’s shaded surfaces. In the office and retail building simulations, these shades are assumed to represent eaves that project outward at the roof level. In Figure 17, the user has the option to change the length of the projection of the shade for each of the four building walls. These shades are repeated for each floor of the building.

In Figure 18, the user can change the inputs that describe the building’s construction, incuding the roof, walls, windows and floor. The inputs for the roof and walls include the insulation levels and the color of the roof or walls that affects the solar absorptivity. The inputs for the window include the window frame type, window U-value, Solar Heat Gain Coefficient (SHGC), and window-to-wall area, which is fixed for all orientations[16]. Floor inputs include the floor construction and insulation values.

In Figure 19, the user is allowed to change the HVAC system inputs, including the type of system, economizer operation, and information about the building’s fans. Figure 20 allows the user to change details about the building’s heating and cooling plant, including the type of heating, cooling and water heating fuel, and the efficiencies of the different equipment.

[16] This feature is intended to change in the next version of the emissions calculator to allow for varying window to wall areas on different orientations.

Figure 14: Office Building Data Entry Screen (Project Input).

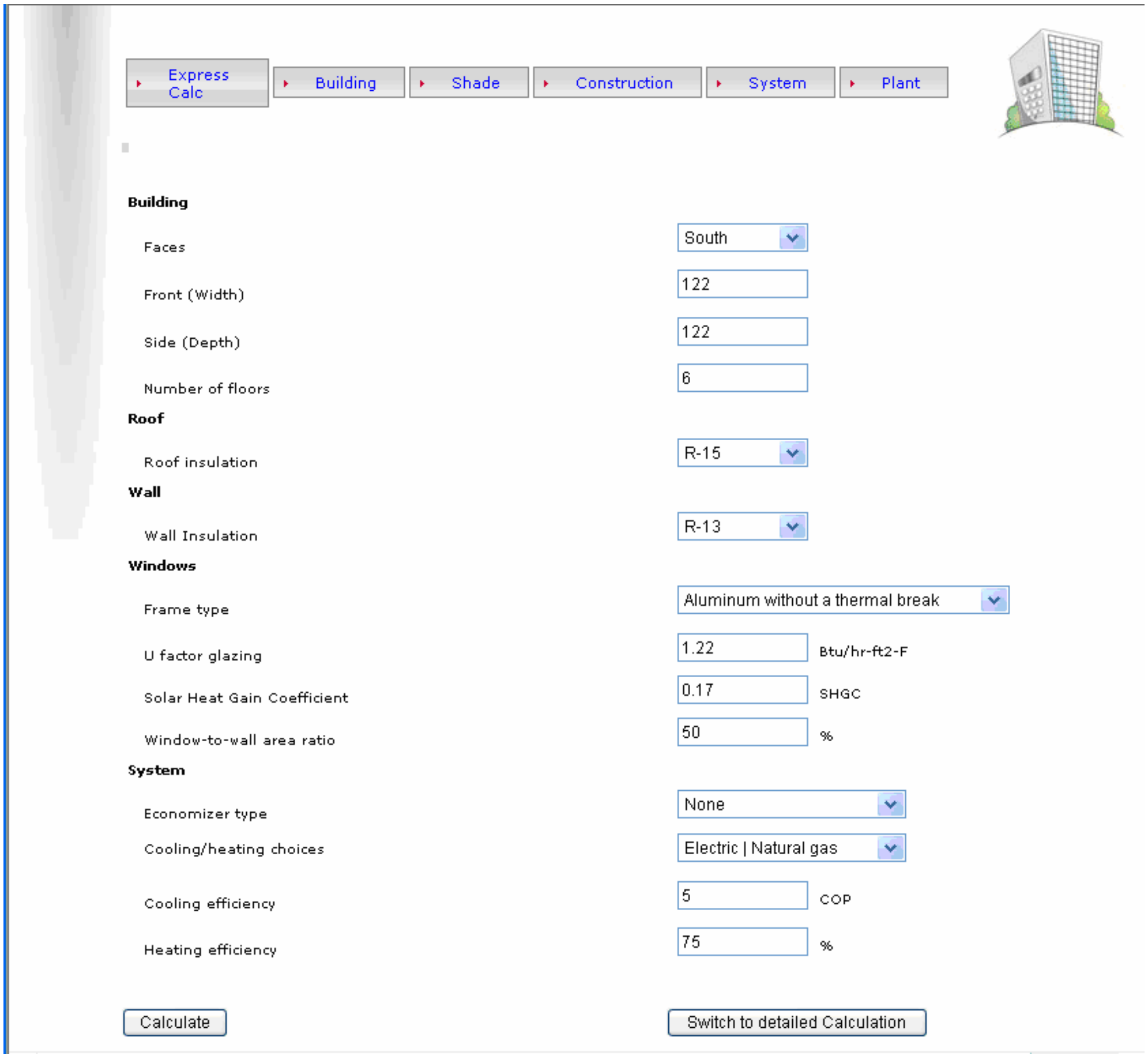


Figure 15: Office Building Data Entry Screen (Express Input).

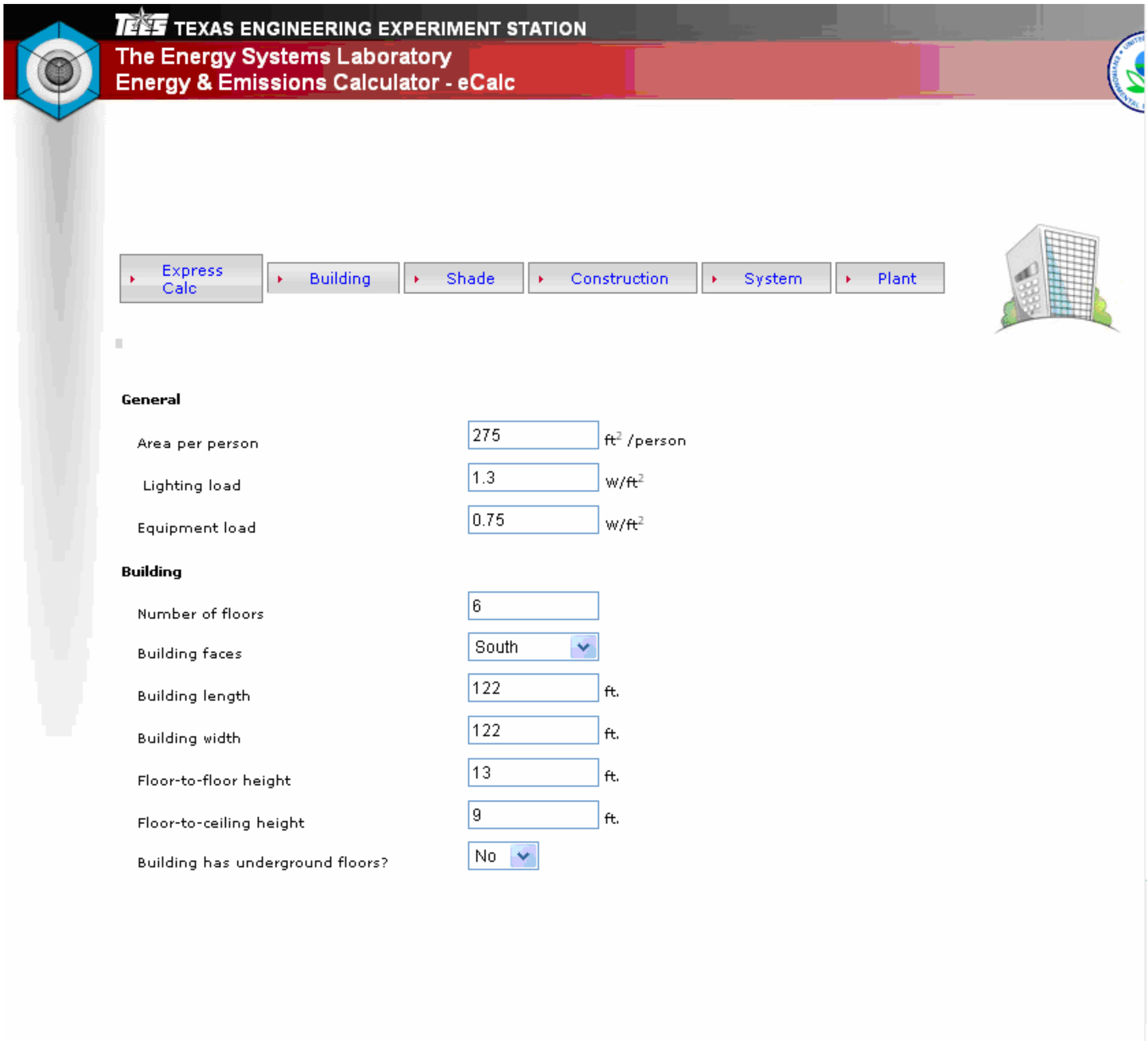


Figure 16: Office Building Data Entry Screen (Detailed Building Input).

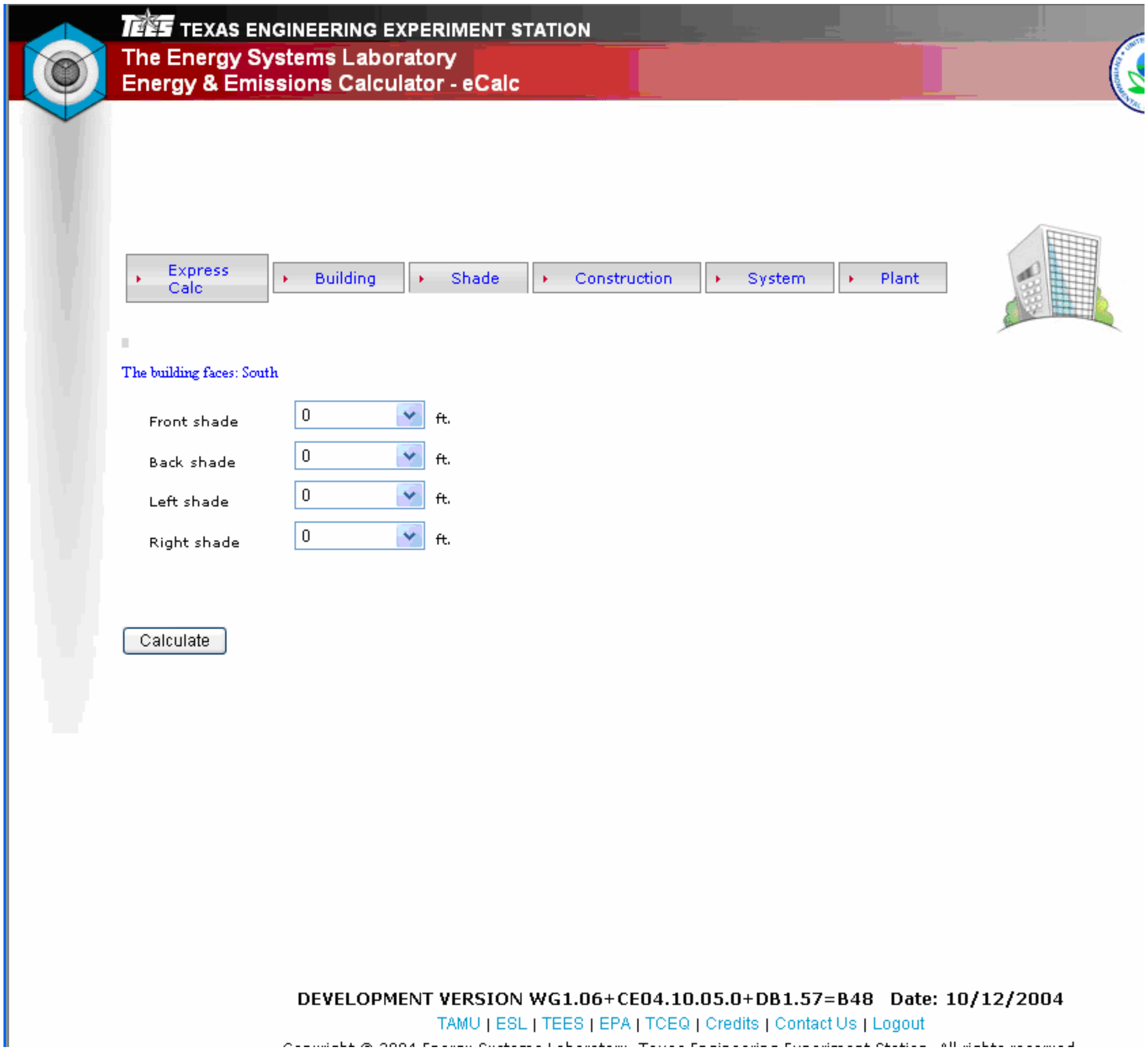


Figure 17: Office Building Data Entry Screen (Detailed Shade Input).

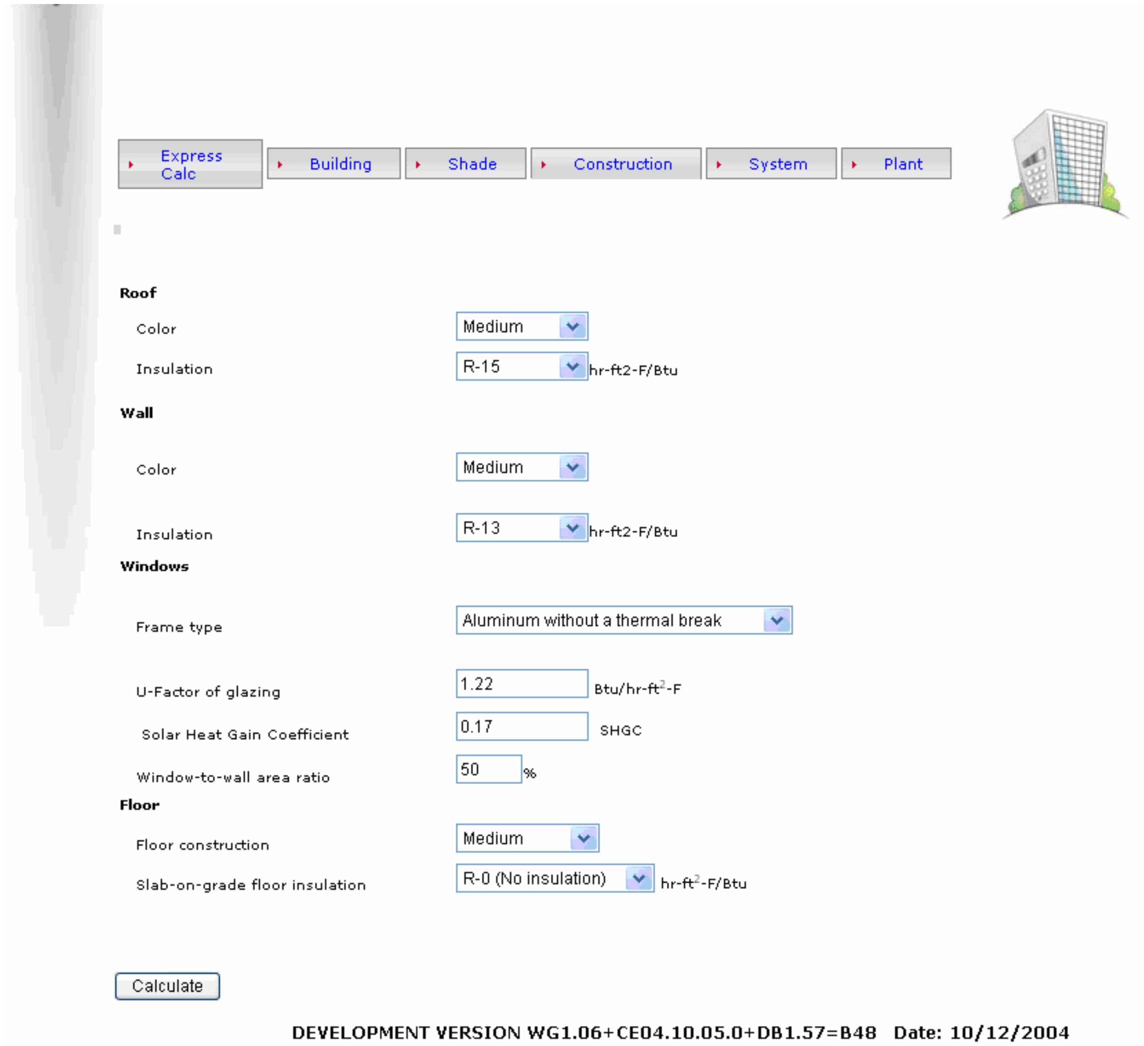


Figure 18: Office Building Data Entry Screen (Detailed Construction Input).

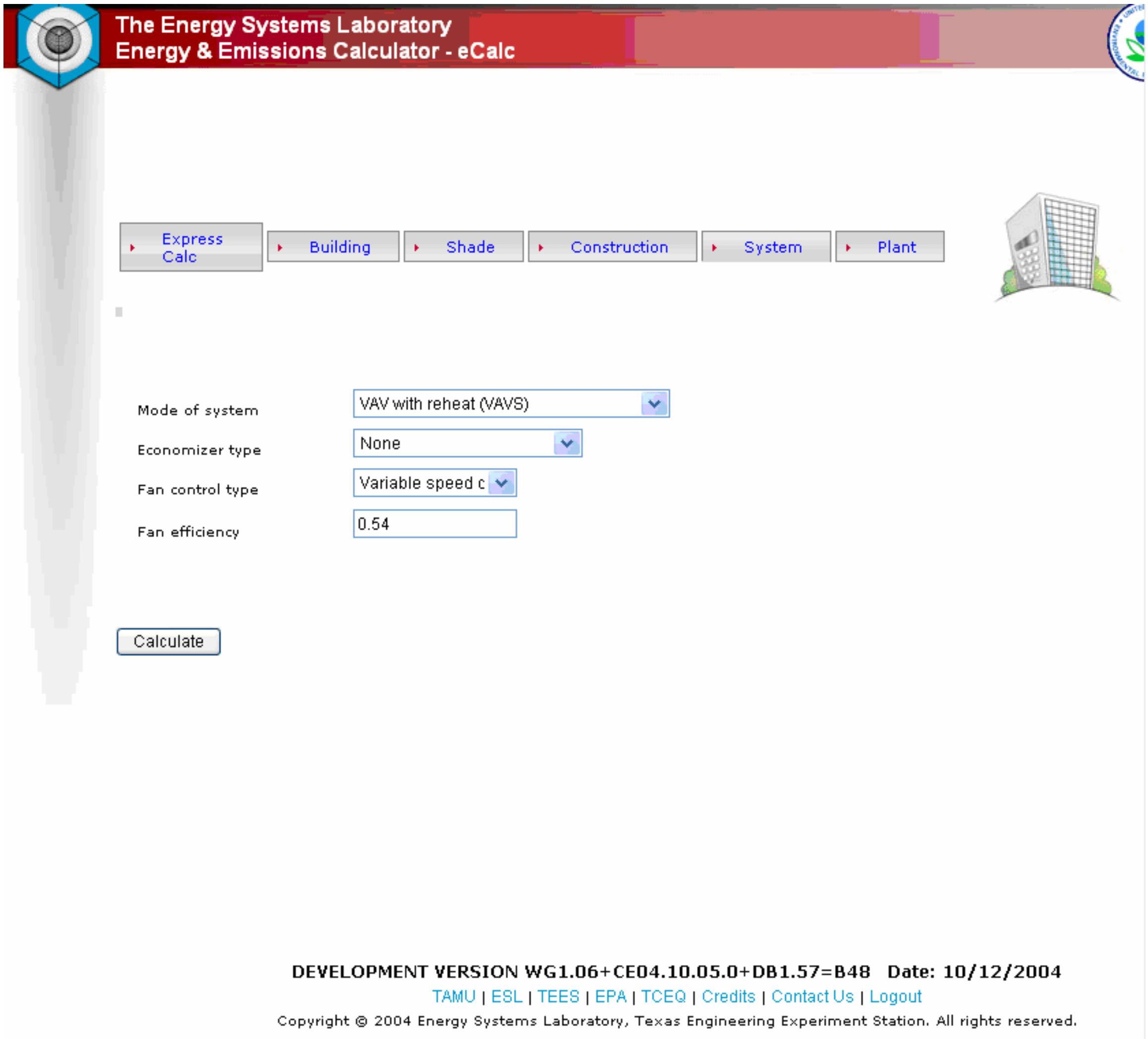


Figure 19: Office Building Data Entry Screen (Detailed System Input).

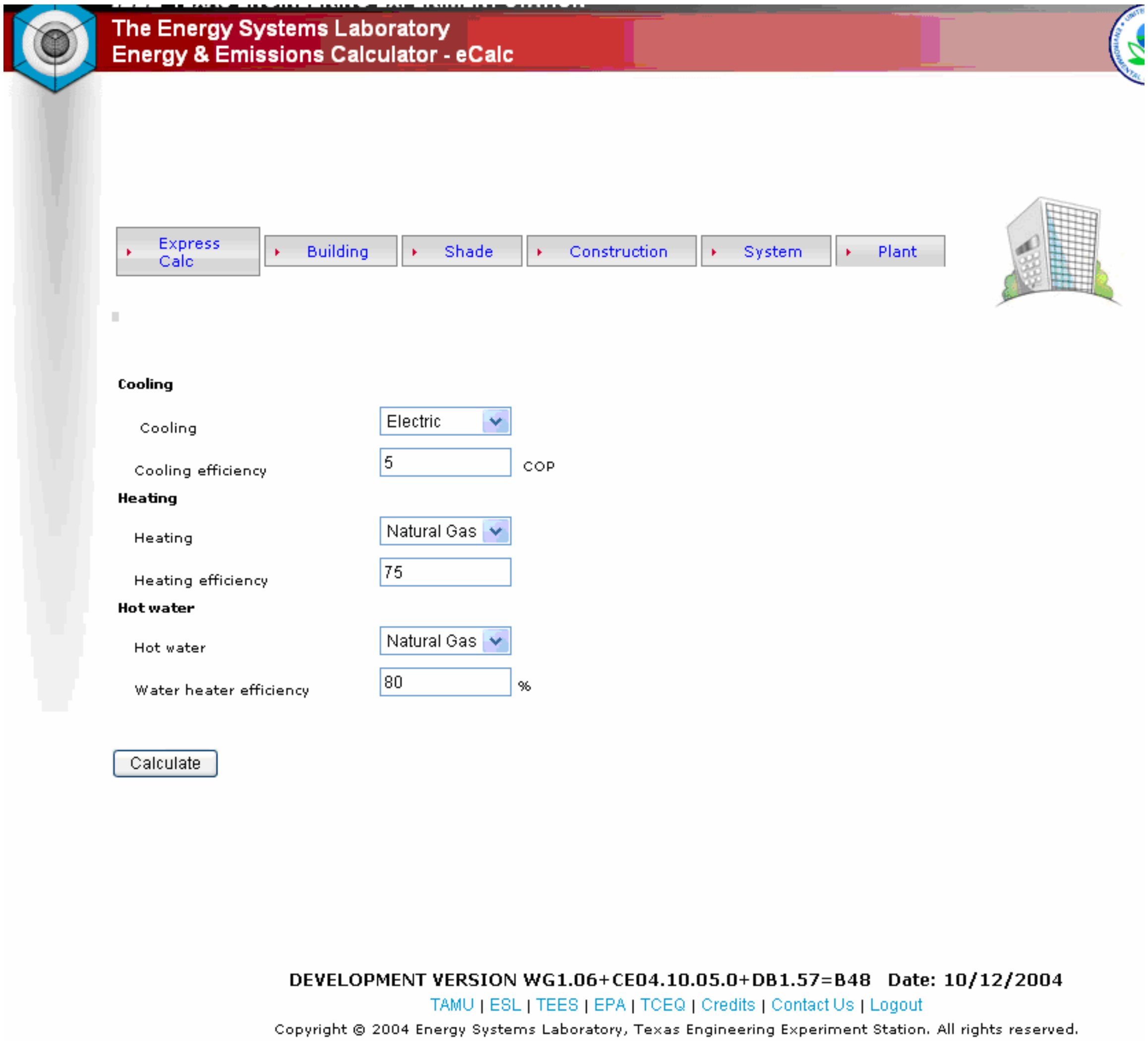


Figure 20: Office Building Data Entry Screen (Detailed Plant Input).

2.2.3.2 Office and Retail Analysis Description

When the user submits their commercial building project for analysis, the emissions calculator performs a series of calculations, as indicated in Figure 21. For each analysis, the user's building description input is compared with pre-code values (Table 11)[17] and code-compliant values (Table 12)[18]. These user-defined input parameters are then passed to the DOE-2 simulation program along with additional, pre-defined parameters (Table 13 and Table 14) and the 1999 weather data[19] associated with the county. The DOE-2 program then generates three output files (i.e., one output for pre-code simulation, one for the code-compliant simulation, and one for the user-defined building) as shown in Table 15, Table 16, and Table 17. In Table 15, the DOE-2 Building Energy Performance Summary (BEPS) output is shown from which the building's energy use (Btu) is extracted. In Table 16, the DOE-2 Building Energy Performance Summary Utility Units (BEPU) output is shown from which the building's energy use (kWh, Therms) is extracted. Finally, in Table 17, the DOE-2 Hourly-Report is shown for August 19, 1999, which is used to calculate the peak-day energy and emissions savings.

In the next step of the analysis, in a similar fashion as the residential simulation, the emissions calculator calculates the NOx, SOx, and CO_2 using the USEPA's eGRID database. These results are then reported by the emissions calculator in a format that is similar to that shown in Table 10 for residential and emailed to the user as HTML and XML files.

[17] These pre-code values assume the building is built to be compliant with ASHRAE Standard 90.1-1989 (ASHRAE 1989).
[18] The code-compliant values assume the building is built to be compliant with ASHRAE Standard 90.1- 1999 (ASHRAE 1999).
[19] See Section 0 for additional information on the 1999 weather data.

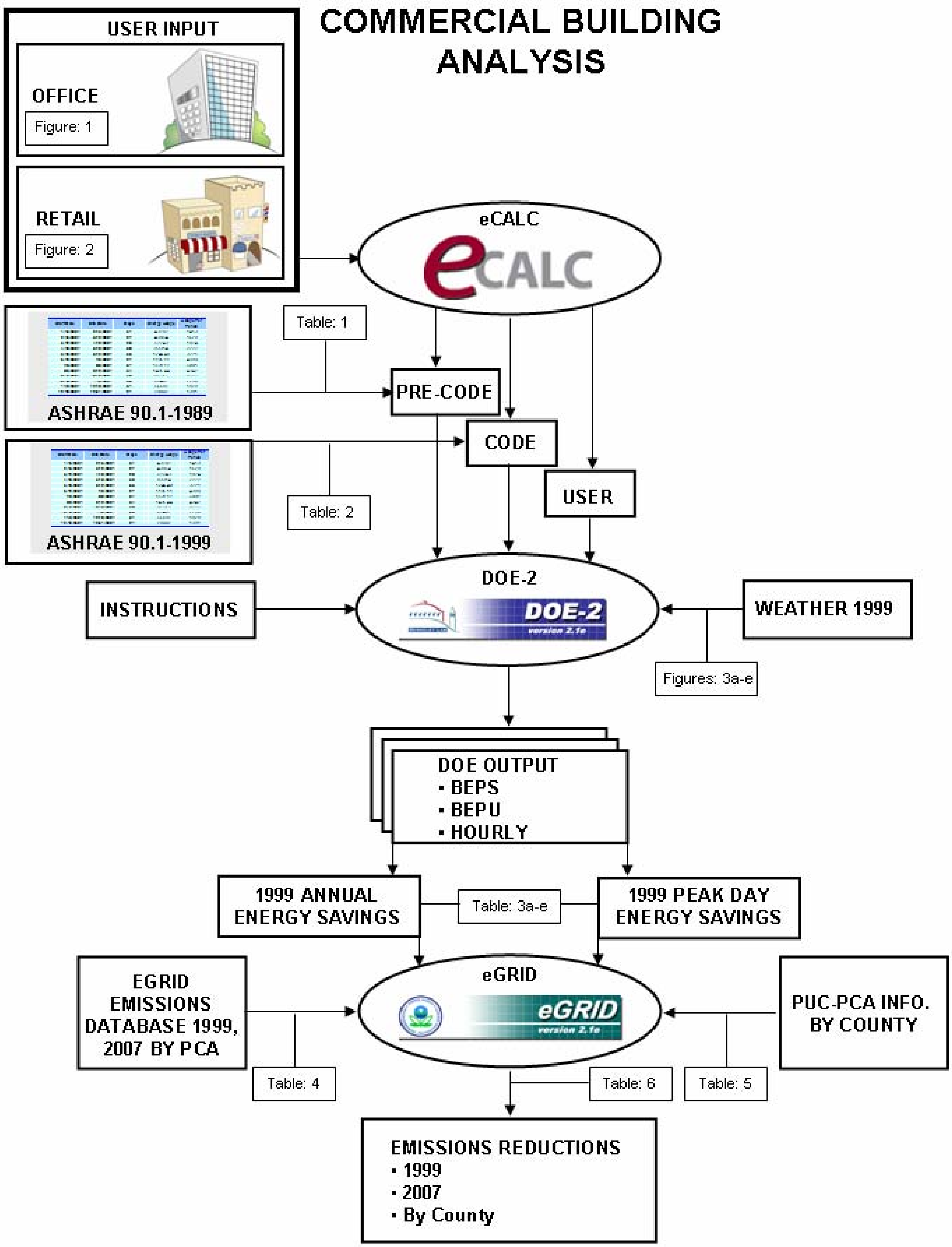


Figure 21: Office and Retail Building Analysis Flowchart.

ALTERNATE COMPONENT PACKAGES FOR: TABLE NUMBER: 8A- 10

HDD50 =	1 - 1000
CDD65 =	2001 - 3250
VSEW =	560 - 845
HDD65 =	1 - 3000

Baton Rouge LA, Charleston SC, Columbia SC, Houston TX, Jackson MS, Lake Charles LA, Lufkin TX, Macon GA, Meridian MS, Mobile AL, Montgomery AL, New Orleans LA, Port Arthur TX, Savannah GA, Shreveport LA

FENESTRATION (Max. Pct. Fenestr.)

INTERNAL LOAD DENSITY (ILD) RANGE	PROJECTION FACTOR (PF)	SHADING COEFF RANGE (SCx)	BASE CASE Uof 1.15 to 0.82	BASE CASE Uof 0.81 to 0	BASE CASE Uof N/A	PERIMETER DAYLIGHTING Uof 1.15 to 0.82	PERIMETER DAYLIGHTING Uof 0.81 to 0	PERIMETER DAYLIGHTING Uof 0.81 to 0 (VLT>=SC)
0 - 1.50	0.000 - 0.249	1.000 - 0.71	19	19		21	22	22
		0.709 - 0.60	23	24		26	27	27
		0.599 - 0.50	27	28		30	32	32
		0.499 - 0.38	32	34		36	38	38
		0.379 - 0.25	41	44		45	49	50
		0.249 - 0.00	59	66		63	72	73
	0.250 - 0.499	1.000 - 0.71	26	27		29	31	31
		0.709 - 0.60	32	34		36	38	38
		0.599 - 0.50	38	40		41	44	45
		0.499 - 0.38	44	47		48	53	54
		0.379 - 0.25	55	61		60	67	69
	0.500 +	1.000 - 0.71	34	36		38	40	41
		0.709 - 0.60	41	44		46	49	50
		0.599 - 0.50	48	52		52	58	59
		0.499 - 0.38	56	61		60	68	69
1.51 - 3.00	0.000 - 0.249	1.000 - 0.71	15	15		21	21	23
		0.708 - 0.60	18	18		26	27	28
		0.599 - 0.50	22	22		30	31	33
		0.499 - 0.38	26	27		36	38	40
		0.379 - 0.25	34	35		46	49	52
		0.249 - 0.00	49	53		65	72	76
	0.250 - 0.499	1.000 - 0.71	21	21		29	30	32
		0.709 - 0.60	26	26		36	38	40
		0.599 - 0.50	30	31		42	45	47
		0.499 - 0.38	36	37		49	53	56
		0.379 - 0.25	46	49		61	68	72
	0.500 +	1.000 - 0.71	27	28		38	40	42
		0.709 - 0.60	33	35		46	49	52
		0.599 - 0.50	39	41		53	58	61
		0.499 - 0.38	46	49		61	68	72
3.01 - 3.50	0.000 - 0.249	1.000 - 0.71	12	12		19	20	22
		0.709 - 0.60	15	15		24	25	27
		0.599 - 0.50	18	18		28	29	32
		0.499 - 0.38	22	22		33	35	38
		0.379 - 0.25	28	29		43	46	50
		0.249 - 0.00	42	45		61	68	73
	0.250 - 0.499	1.000 - 0.71	17	17		27	28	31
		0.709 - 0.60	21	22		33	35	38
		0.599 - 0.50	25	26		39	42	45
		0.499 - 0.38	30	31		46	50	54
		0.379 - 0.25	39	41		57	64	69
	0.500 +	1.000 - 0.71	23	23		36	37	41
		0.709 - 0.60	28	29		43	46	50
		0.599 - 0.50	33	34		50	54	59
		0.499 - 0.38	39	41		57	64	69

Daylight Sensing Controls

OPAQUE WALL (Max. Uow)

LIGHT WEIGHT WALL | MASS WALL

ILD 0 - 1.50:

Uow (HC<5)	HC RANGE	PCT FEN	INT INS	EXT INS
0.15	HC >= 5	19	0.17	0.24
	HC >= 10	19	0.23	0.33
	HC >= 15	19	0.30	0.36
	HC >= 5	73	0.17	0.24
	HC >= 10	73	0.22	0.30
	HC >= 15	73	0.28	0.33

ILD 1.51 - 3.00:

Uow (HC<5)	HC RANGE	PCT FEN	INT INS	EXT INS
0.15	HC >= 5	15	0.17	0.24
	HC >= 10	15	0.24	0.36
	HC >= 15	15	0.34	0.39
	HC >= 5	76	0.17	0.24
	HC >= 10	76	0.23	0.33
	HC >= 15	76	0.30	0.36

ILD 3.01 - 3.50:

Uow (HC<5)	HC RANGE	PCT FEN	INT INS	EXT INS
0.15	HC >= 5	12	0.17	0.24
	HC >= 10	12	0.25	0.36
	HC >= 15	12	0.34	0.39
	HC >= 5	73	0.17	0.24
	HC >= 10	73	0.23	0.33
	HC >= 15	73	0.31	0.37

OTHER CRITERIA

	Minimum R-Value				Max Uo
WALL BELOW GRADE:		0		ROOF:	0.066
UNHEATED SLAB				WALL ADJACENT TO	
ON GRADE:	24"	36"	48"	UNCOND SPACE:	0.24
Horizontal	0	0	0	FLOOR OVER	
Vertical	0	0	0	UNCOND. SPACE:	0.11

Table 11: Office and Retail Building Analysis Flowchart (Table 1: ASHRAE Data from ASHRAE Standard 90.1-1989).

TABLE B-6
Building Envelope Requirements (HDD65: 901-1800, CDD50: 5401-7200)

Opaque Elements	Nonresidential Assembly Maximum	Nonresidential Insulation Min. R-Value	Residential Assembly Maximum	Residential Insulation Min. R-Value	Semiheated Assembly Maximum	Semiheated Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.063	R-15.0 ci	U-0.218	R-3.8 ci
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.167	R-6.0
Attic and Other	U-0.034	R-30.0	U-0.034	R-30.0	U-0.081	R-13.0
Walls, Above Grade						
Mass	U-0.580	NR	U-0.151*	R-5.7 ci*	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.184	R-6.0
Steel Framed	U-0.124	R-13.0	U-0.124	R-13.0	U-0.352	NR
Wood Framed and Other	U-0.089	R-13.0	U-0.089	R-13.0	U-0.292	NR
Wall, Below Grade						
Below Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.137	R-4.2 ci	U-0.107	R-6.3 ci	U-0.322	NR
Steel Joist	U-0.052	R-19.0	U-0.052	R-19.0	U-0.350	NR
Wood Framed and Other	U-0.051	R-19.0	U-0051	R-19.0	U-0.282	NR
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.730	NR	F-0.730	NR
Heated	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Non-Swinging	U-1.450		U-1.450		U-1.450	
Fenestration	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**	**Assembly Max. U (Fixed/ Operable)**	**Assembly Max. SHGC (All Orientations/ North-Oriented)**
Vertical Glazing, % of Wall						
0-10.0%	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.39 $SHGC_{north}$-0.61	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.61 $SHGC_{north}$-0.61	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-NR $SHGC_{north}$NR
10.1-20.0%	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.25 $SHGC_{north}$-0.61	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.44 $SHGC_{north}$-0.61	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-NR $SHGC_{north}$NR
20.1-30.0%	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.25 $SHGC_{north}$-0.61	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.44 $SHGC_{north}$-0.61	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-NR $SHGC_{north}$NR
30.1-40.0%	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.25 $SHGC_{north}$-0.61	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.40 $SHGC_{north}$-0.61	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-NR $SHGC_{north}$NR
40.1-50.0%	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.17 $SHGC_{north}$-0.42	U_{fixed}-1.22 U_{oper}-1.27	$SHGC_{all}$-0.29 $SHGC_{north}$-0.41	U_{fixed}-0.98 U_{oper}-1.02	$SHGC_{all}$-NR $SHGC_{north}$NR
Skylight with Curb, Glass, % of Roof						
0-2.0%	U_{all}-1.98	$SHGC_{all}$-0.39	U_{all}-1.98	$SHGC_{all}$-0.36	U_{all}-1.98	$SHGC_{all}$-NR
2.1-5.0%	U_{all}-1.98	$SHGC_{all}$-0.25	U_{all}-1.98	$SHGC_{all}$-0.19	U_{all}-1.98	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0-2.0%	U_{all}-1.90	$SHGC_{all}$-0.65	U_{all}-1.90	$SHGC_{all}$-0.27	U_{all}-1.90	$SHGC_{all}$-NR
2.1-5.0%	U_{all}-1.90	$SHGC_{all}$-0.39	U_{all}-1.90	$SHGC_{all}$-0.27	U_{all}-1.90	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0-2.0%	U_{all}-1.36	$SHGC_{all}$-0.39	U_{all}-1.36	$SHGC_{all}$-0.36	U_{all}-1.36	$SHGC_{all}$-NR
2.1-5.0%	U_{all}-1.36	$SHGC_{all}$-0.25	U_{all}-1.36	$SHGC_{all}$-0.19	U_{all}-1.36	$SHGC_{all}$-NR

Table 12: Office and Retail Building Analysis Flowchart (Table2: ASHRAE Data from ASHRAE Standard 90.1- 1999).

NAME	DESCRIPTION	DEFAULT	STATUS	COMMENT
LOADS				
b01	Quick or thermal mode (Q or T)	Quick (Q)	Fixed	Q simulates the building as massless, T will include thermal mass
b02	Location	Bastrop (BAS)	User Defined	41 counties linked to 9 TRY packed weather files according to climate zone
b03	Azimuth of building (degree)	0	User Defined	Orientation of the building
b04	Length of building (ft)	122	User Defined	
b05	Width of building (ft)	122	User Defined	
b06	Floor to ceiling height (ft)	9	User Defined	
b07	Door height (ft)	7	Fixed	
b08	Door width (ft)	6	Fixed	
b09	Run year	2000	User Defined	
b10	Floor to floor height (ft)	13	User Defined	This defines the plenum height in conjunction with b06
b11	Number of floor	6	User Defined	
b12	Perimeter depth (ft)	15	Fixed	Used for thermal zoning
b13	Void			
b14	Underground floor mode	No (N)	User Defined	This allows the user to activate/deactivate underground floors
b15	Front wall: Attached to another building?	No (N)	User Defined	These 4 parameters are used to attach buildings to the different orientations of the model for the retail scenario
b16	Right wall: Attached to another building?	No (N)	User Defined	
b17	Back wall: Attached to another building?	No (N)	User Defined	
b18	Left wall: Attached to another building?	No (N)	User Defined	
b19	Building type	Office (O)	User Defined	Allows the user to switch between Office and Retail
b20	Code compliance	Code (C)	User Defined	Allows user to run user defined model or either of ASHRAE 90.1 1989 or 1999
c01	Roof absorptance	0.45	User Defined	c01 and c03 are used to determine "roof color"
c02	Roof roughness	1	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c03	Roof outside emissivity	0.89	User Defined	c01 and c03 are used to determine "roof color"
c04	Roof insulation R-value (hr-sq.ft-F/Btu)	R-15	User Defined	
c05	Wall absorptance	0.57	User Defined	c05 and c07 are used to define "wall color"
c06	Wall roughness	2	Fixed	This is used to calculate the outside film coefficient for heat transfer calculations, DOE-2 allows values from 1 to 6 increasing in smoothness
c07	Wall outside emissivity	0.9	User Defined	c05 and c07 are used to define "wall color"
c08	Wall insulation R-value (hr-sq.ft-F/Btu)	R-13	User Defined	
c09	Ground reflectance	0.24	Fixed	This defines the fraction of sunlight reflected from the ground
c10	Void			
c11	U-Factor of glazing (Btu/hr-sq.ft-F)	1.22	User Defined	
c12	Solar Heat Gain Coefficient(SHGC)	0.17	User Defined	
c13	Number of pane of glazing	1	Fixed	
c14	Frame absorptance of glazing	0.7	Fixed	
c15	Frame type - A,B,C,D,E	Aluminum w/o thermal break (A)	User Defined	Allows user to select from 5 different frame types
c16	Void			
c17	Floor weight (lb/sq-ft)	70	User Defined	This corresponds to medium construction, user has a choice of light, medium or heavy construction
c18	Slab-on-grade floor insulation R-value (Exterior insulation, horizontal) (hr-sq.ft-F/Btu)	R-0 (A)	User Defined	User can choose from 9 insulation R-values and insulation depths
c19	Slab-on-grade floor R-value (hr-sq.ft-F/Btu)	0.88	Fixed	
c20	Below-grade wall insulation R-value (hr-sq.ft-F/Btu) (Exterior insulation, vertical, basement wall = 8 ft)	R-0 (A)	User Defined	User can choose from 9 insulation R-values
c21	Below-grade wall R-value (concrete wall) (hr-sq.ft-F/Btu)	0.88	Fixed	
c22	Void			
c23	Floor R-value	1.67	Fixed	
c24	Void			
c25	Ceiling R-value (hr-sq.ft-F/Btu)	1.89	Fixed	
c26	Interior wall R-value (hr-sq.ft-F/Btu)	2.01	Fixed	
c27	Percent window-front (%)	50	User Defined	
c28	Percent window-right (%)	50	User Defined	
c29	Percent window-back (%)	50	User Defined	
c30	Percent window-left (%)	50	User Defined	
sp01	void			
sp02	void			
sp03	Area per person (ft^2/person) for office	275	User Defined	
sp04	Lighting load (W/ft2) for office	1.3	User Defined	
sp05	Equipment load (W/ft2) for office	0.75	User Defined	
sp06	Area per person (ft^2/person) for retail	300	User Defined	
sp07	Lighting load (W/ft2) for retail	1.9	User Defined	
sp08	Equipment load (W/ft2) for retail	0.25	User Defined	
s01	Front Shade (S)	0	User Defined	
s02	Back Shade (N)	0	User Defined	
s03	Left Shade (W)	0	User Defined	
s04	Right Shade (E)	0	User Defined	

Table 13: Office and Retail Building Analysis Flowchart (Complete Listing of Input Parameters for Office and Retail model: part 1).

NAME	DESCRIPTION	DEFAULT	STATUS	COMMENT
SYSTEM				
sy01	Mode of system	Variable air volume (2)	User Defined	User can choose from Packaged single zone, variable air volume or packaged variable volume system
sy02	Cooling Capacity of cooling system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy03	Heating Capacity of heating system (Btu/hr)	0	Fixed	DOE-2 is autosizing the system
sy04	Seasonal Energy Efficiency Ratio (SEER) for PVAVS and PSZ	10	User Defined	
sy05	ANNUAL FUEL UTILIZATION EFFICIENCY (AFUE) for PSZ	0.8	User Defined	
sy06	**Spare parameter for systems other than VAVS**HEATING SEASONAL PERFORMANCE FACTOR (HSPF)	6.8	User Defined	Unused, since heatpump systems are not included in the office/retail scenario
sy07	**Spare parameter for Pilot light	0	Fixed	Unused
sy08	**Spare parameter for Pilot light	0	Fixed	Unused
sy09	**Spare parameter for Pilot light	0	Fixed	Unused
sy10	Void			
sy11	Exterior lighting (kW)	0	Fixed	
sy12	Void			
sy13	Fan control type	Variable frequency drives (1)	User Defined	User can choose from 4 different type of fan control
sy14	Economizer type	None (1)	User Defined	
sy15	Economizer drybulb limit (F) (use when economizer type(sy14) = dry bulb(2))	65	Fixed	This corresponds to the temperature above which the outside air dampers return to the minimum position
sy16	User input for numbers of fans	Autosized (A)	Fixed	Autosized by DOE-2
sy17	Number of Fans	6	Fixed	equal to the number of floors
sy18	Supply fan total pressure (in W.G)	5.5	Fixed	
sy19	Supply fan efficiency	0.54	Fixed	
sy20	Return fan total pressure (in W.G)	2	Fixed	
sy21	Return fan efficiency	0.51	Fixed	
sy22	Supply motor efficiency	0.5	Fixed	
sy23	Return motor efficiency	0.5	Fixed	
sy24	User input for DHW gallon/hr-person	Autosized (A)	Fixed	The size of DHW depends on the gallons per hour per person requirements of ASHRAE 90.1
sy25	Maximum DHW gallon/h-person (maximum hourly, to be used with occupancy schedule)	0.4	Fixed	
PLANT				
p01	Chiller type	Electric Centrifugal (1)	Fixed	
p02	Number of chillers	1	Fixed	
p03	Chillers size (MBtu/h)	-999	Fixed	Chiller is being autosized by DOE-2
p04	Condenser type	water-cooled (W)	Fixed	
p05	COP	5	User Defined	
p06	Switch for a chiller sizing	Autosized (A)	Fixed	Chiller is being autosized by DOE-2
p07	Cooling tower type	Open tower (O)		
p08	Void			
p09	Gpm/hp	38.2	Fixed	Value from ASHRAE 90.1 1999 for axial fan cooling towers
p10	Cooling tower capacity control	Two-speed fan (1)	Fixed	
p11	Boiler type	Gas fired-hotwater boiler (1)	User Defined	User can choose from gas fired or electric boilers
p12	Number of boilers	1	Fixed	
p13	Boiler size (MBtu/h)	-999	Fixed	Boiler is being autosized by DOE-2
p14	Boiler fuel type	Gas (G)	Fixed	Depends on the value of p10
p15	Boilers efficiency (Et,Ec,AFUE) (%)	80	User Defined	
p16	Switch for a boiler sizing	Autosized (A)	Fixed	Boiler is being autosized by DOE-2
p17	Void			
p18	DHW heater type	Gas water heater (1)	User Defined	User can choose from gas fired or electric water heaters
p19	Number of DHW heater	1	Fixed	
p20	DHW size (MBtu/h)	-999	Fixed	Water heater is being autosized by DOE-2
p21	DHW fuel type	Gas (G)	Fixed	Depends on the value of p18
p22	DHW heater Efficiency (Et,Ec,Energy factor) (%)	54	User Defined	
p23	Switch for a DHW heater sizing	Autosized (A)	Fixed	Water heater is being autosized by DOE-2
p24	DHW Storage Capacity (gal)	75	Fixed	

Table 14: Office and Retail Building Analysis Flowchart (Complete Listing of Input Parameters for Office and Retail model: part 2).

```
1SB5 PROJECT                        COMMERCIAL PROTOTYPE                  DOE-2.1E-119  Fri Oct  8 13:32:56 2004PDL
RUN  1
 PLANTS DESCRIPTION                 VARIABLE AIR VOLUME SYSTEM
 REPORT- BEPS  BUILDING ENERGY PERFORMANCE SUMMARY                                     WEATHER FILE- GGG 1999

------------------------------------------------------------------------------------------------------------------------
------


                              ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                              UNITS: MBTU

                            CATEGORY OF USE
                            ---------------

                               AREA LIGHTS       1068.1           0.0

                              MISC EQUIPMT        616.2           0.0

                                SPACE HEAT         48.0        1219.6

                                SPACE COOL        679.2           0.0

                               HEAT REJECT        200.2           0.0

                              PUMPS & MISC        174.6           0.0

                                 VENT FANS        316.7           0.0

                              DOMHOT WATER          0.0          44.7
                                             ----------    ----------

                                     TOTAL       3103.1        1264.3


                   TOTAL SITE ENERGY      4367.37 MBTU     48.9 KBTU/SQFT-YR GROSS-AREA     48.9 KBTU/SQFT-YR NET-AREA
                   TOTAL SOURCE ENERGY   10574.41 MBTU    118.4 KBTU/SQFT-YR GROSS-AREA    118.4 KBTU/SQFT-YR NET-AREA

                   PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE -  0.0
                   PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED                -  0.1

                   NOTE:  ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.
```

Table 15: Office and Retail Building Analysis Flowchart (Table 3a: Sample of DOE-2.1e Output for Office – BEPS).

```
1SB5 PROJECT                        COMMERCIAL PROTOTYPE                  DOE-2.1E-119  Fri Oct  8 13:32:56 2004PDL
RUN  1
 PLANTS DESCRIPTION                 VARIABLE AIR VOLUME SYSTEM
 REPORT- BEPU  BUILDING ENERGY PERFORMANCE SUMMARY (UTILITY UNITS)                     WEATHER FILE- GGG 1999

------------------------------------------------------------------------------------------------------------------------
------


                              ENERGY TYPE:   ELECTRICITY   NATURAL-GAS
                               SITE UNITS:       KWH          THERM

                            CATEGORY OF USE
                            ---------------

                               AREA LIGHTS      312984.            0.

                              MISC EQUIPMT      180555.            0.

                                SPACE HEAT       14072.        12196.

                                SPACE COOL      198993.            0.

                               HEAT REJECT       58671.            0.

                              PUMPS & MISC       51157.            0.

                                 VENT FANS       92784.            0.

                              DOMHOT WATER           0.          447.
                                             ----------    ----------

                                     TOTAL      909185.        12643.


          TOTAL ELECTRICITY    909185. KWH        10.181 KWH    /SQFT-YR GROSS-AREA   10.181 KWH    /SQFT-YR NET-AREA
          TOTAL NATURAL-GAS     12643. THERM       0.142 THERM  /SQFT-YR GROSS-AREA    0.142 THERM  /SQFT-YR NET-AREA

                   PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE =  0.0
                   PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED                =  0.1

                   NOTE:  ENERGY IS APPORTIONED HOURLY TO ALL END-USE CATEGORIES.
```

Table 16: Office and Retail Building Analysis Flowchart (Table 3b: Sample of DOE-2.1e Output for Office – BEPU).

```
1SB5 PROJECT                                COMMERCIAL PROTOTYPE                           DOE-2.1E-119  Fri Oct  8 13:32:56 2004PDL
RUN  1
 PLANTS DESCRIPTION                         VARIABLE AIR VOLUME SYSTEM
 PLOTPLNT           - HOURLY-REPORT
PAGE231 -  1

---------------------------------------------------------------------------------------------------------------------------
------
           PLANT          END-USE        END-USE

           TOTAL          HEATING        DHW HEAT
           ELECTRIC       FUEL           FUEL
           KW             BTU/HR         BTU/HR

           ----(10)       ----(15)       ----(18)
  819 1         16.675    17447.736        500.947
  819 2         16.643    17447.736        500.947
  819 3         16.638    17447.736        500.947
  819 4         16.628    17447.736        500.947
  819 5         16.637    17447.736        500.947
  819 6         16.628    17447.736        500.947
  819 7         16.637    17447.736        500.947
  819 8         16.638    17447.736        500.947
  819 9         16.676    17447.736        500.947
  81910         86.080    17447.736        500.947
  81911         16.690    17447.736        500.947
  81912         94.131    17447.736        500.947
  81913         16.607    17447.736        500.947
  81914        110.417    17447.736        500.947
  81915         16.602    17447.736        500.947
  81916        122.760    17447.736        500.947
  81917         16.610    17447.736        500.947
  81918        125.100    17447.736        500.947
  81919         16.635    17447.736        500.947
  81920        103.804    17447.736        500.947
  81921         16.679    17447.736        500.947
  81922         89.476    17447.736        500.947
  81923         16.677    17447.736        500.947
  81924         78.084    17447.736        500.947
0 DAILY SUMMARY  (AUG 19)
     MN         16.602    17447.736        500.947
     MX        125.100    17447.736        500.947
     SM       1076.153   418745.781      12022.729
     AV         44.840    17447.740        500.947
```

Table 17: Office and Retail Building Analysis Flowchart (Table 3c: Sample of DOE-2.1e Output – Hourly report for August 19, 1999).

2.3 Community Projects

The emissions calculator also calculates the emissions reductions from the municipal projects, such as those that Political Subdivisions are required to report to the Texas State Energy Conservation Office (SECO). These projects include municipal buildings (new construction and retrofits), street lights (new construction and retrofits), traffic lights (new construction and retrofits), municipal water supply and waste-water systems (retrofit only), and wind energy systems (new systems connected to the grid).

2.3.1 Municipal Buildings

The emissions calculator offers two types of projects for municipal buildings – new construction and retrofit projects, which are explained further in the following sections. Access to the two different project types occurs during the selection of the "project classification".

2.3.1.1 Municipal Buildings - New Construction Input Screens

The New Construction input screen can be selected during the project entry screen, as shown in Figure 22. When the user has selected the "new construction" option and submits the project information to the emissions calculator, the calculator redirects the user to the "office" building screen, where the user can then enter the information about the new municipal building. This building will then be compared to both code-compliant and pre-code construction, and the different energy use and emissions levels will be calculated by the emissions calculator using the ASHRAE 90.1-1989 Standard for pre-code construction and ASHRAE 90.1-1999 Standard for the code-compliant construction.

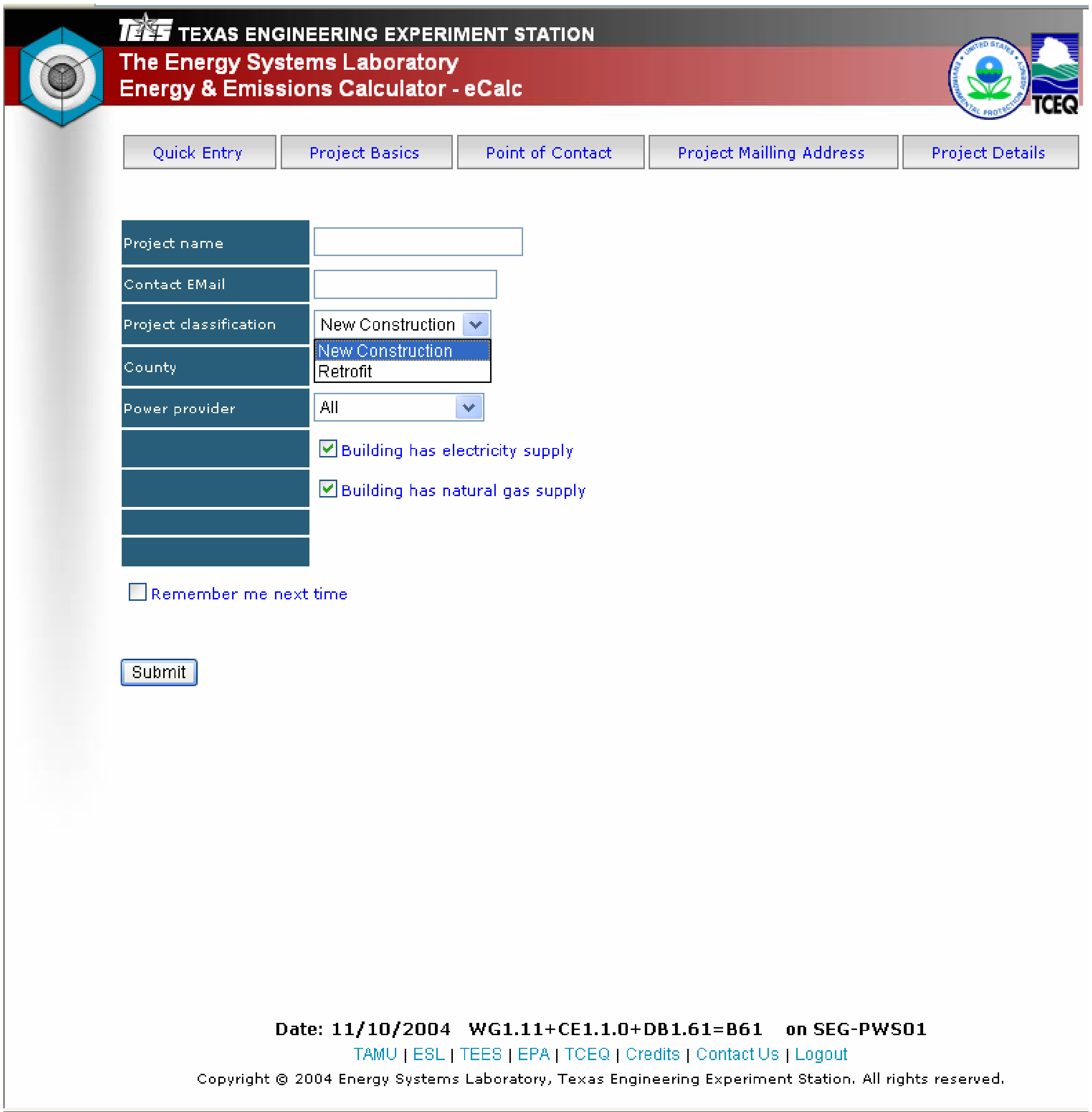


Figure 22: Municipal Buildings New Construction Data Entry Screen (Project Input).

2.3.1.2 Municipal Buildings -Retrofit Building Data Input Screens

The user input screens for municipal building retrofit projects begin with the same project input screen that was used for the municipal building new construction project shown in Figure 23, with the exception that the project classification selection is for retrofit. When the user submits this type of project to the emissions calculator they are directed to the screen shown in Figure 24. This input screen asks for specific information about the building or group of buildings represented by the before-after monthly utility bills. Specifically, the user is asked whether the building has the heating provided by electricity, natural gas, or none, which represents buildings without heating systems. Similar information is asked for the cooling system. When the user completes the screen shown in Figure 24, they are redirected to the screen shown in Figure 25 where they are asked for the beginning date for the 12 months of pre-retrofit data, and the date for the retrofit.

After entering this information, the user can then begin entering the pre-retrofit and post-retrofit data into the screen shown in Figure 26. When the user completes entering 12 months of both the pre-retrofit and post-retrofit data, they press the “done with both bills” button and the project is submitted for analysis.

Figure 23: Municipal Buildings Retrofit Data Entry Screen (Project Input).

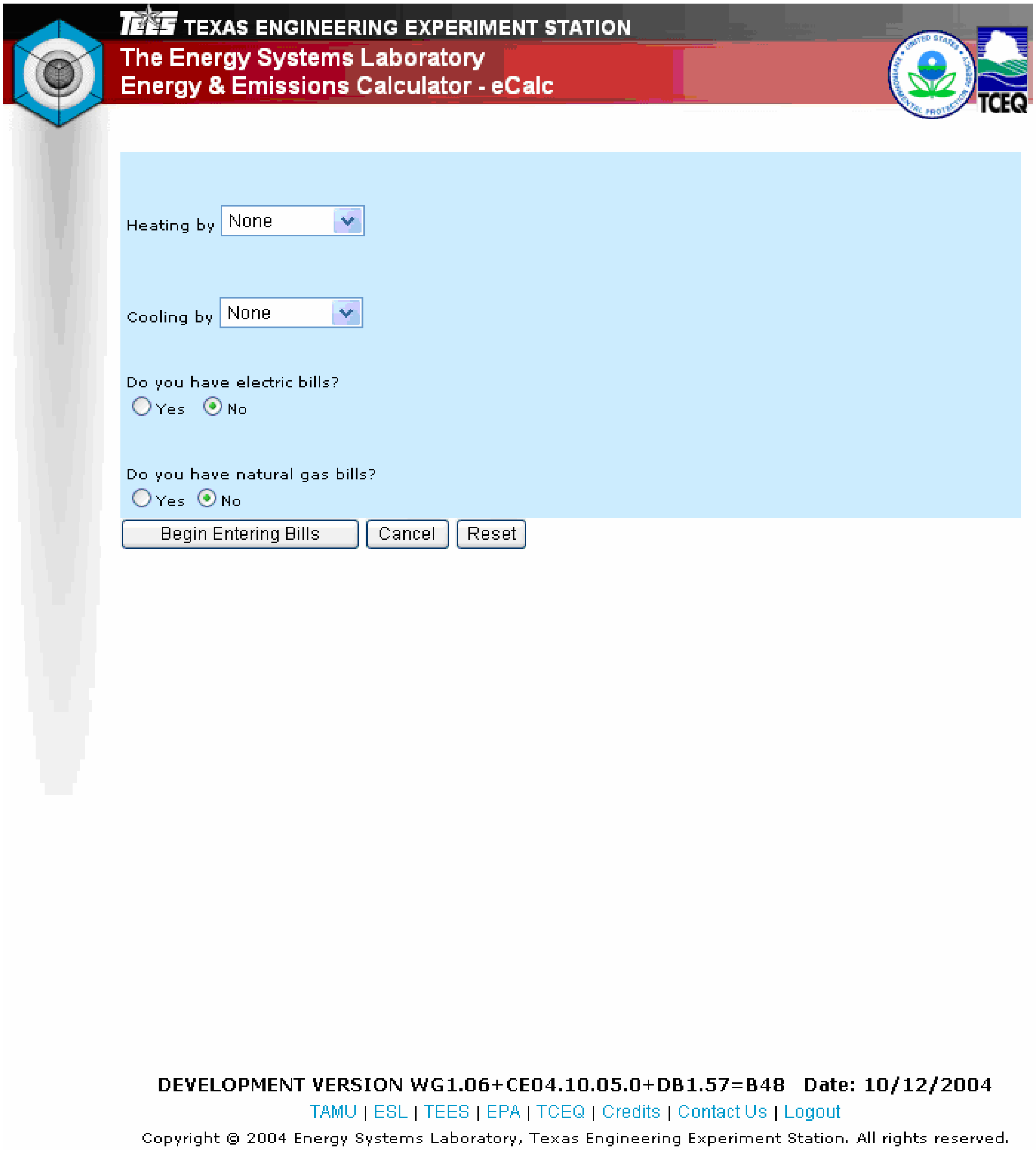


Figure 24: Municipal Buildings Retrofit Data Entry Screen (Heating or Cooling Fuel Input).

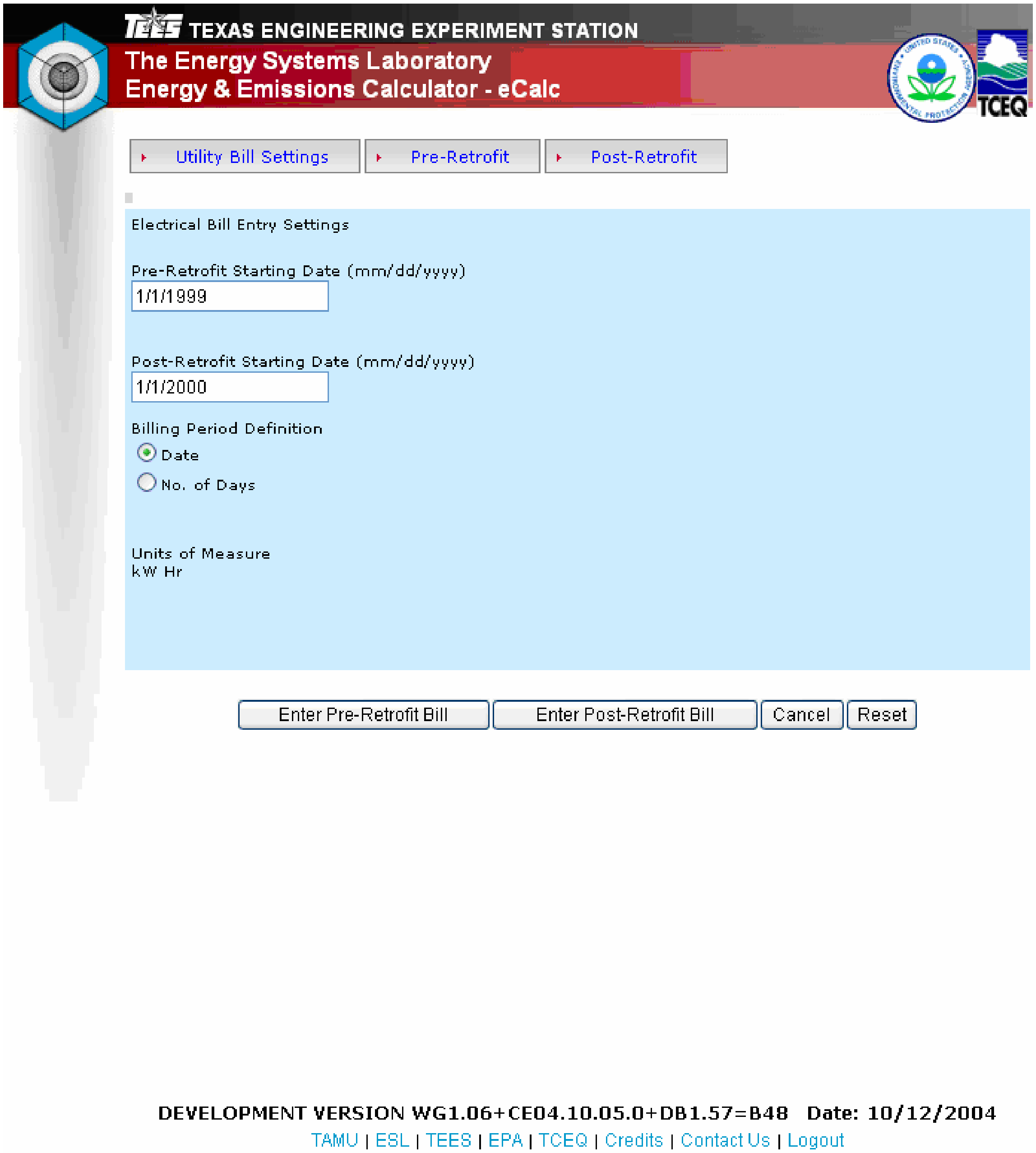
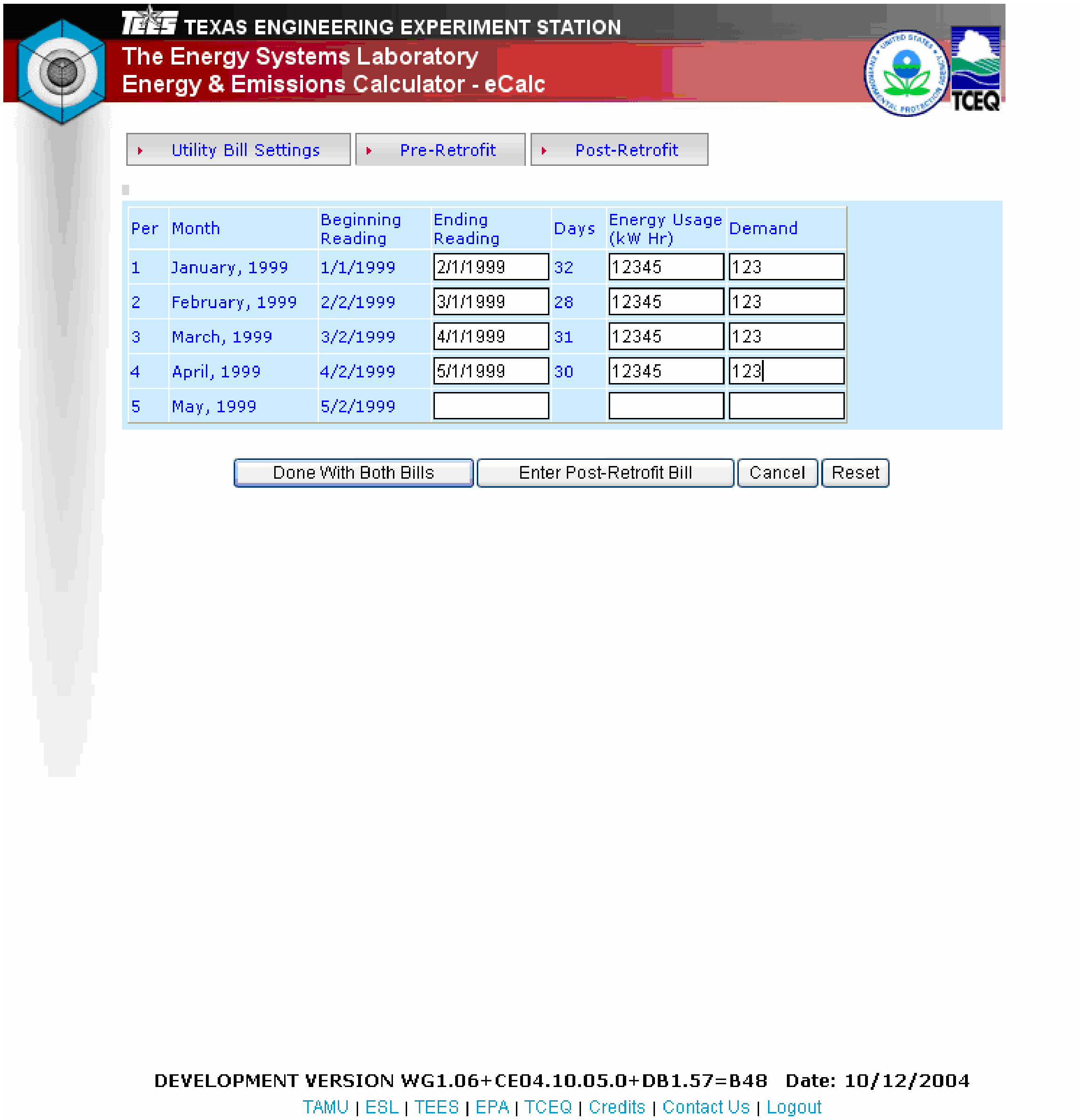


Figure 25: Municipal Buildings Retrofit Data Entry Screen (Project Pre and Post Dates).



Per	Month	Beginning Reading	Ending Reading	Days	Energy Usage (kW Hr)	Demand
1	January, 1999	1/1/1999	2/1/1999	32	12345	123
2	February, 1999	2/2/1999	3/1/1999	28	12345	123
3	March, 1999	3/2/1999	4/1/1999	31	12345	123
4	April, 1999	4/2/1999	5/1/1999	30	12345	123
5	May, 1999	5/2/1999				

Figure 26: Municipal Buildings Retrofit Data Entry Screen (Pre and Post Utility Bill Input).

2.3.1.3 Municipal Buildings - Retrofit Building Analysis Description

When the user submits their municipal building retrofit project for analysis, the emissions calculator performs a series of calculations, as indicated in Figure 27. For each analysis, the user is required to enter 12 pre-retrofit utility bills and 12 post-retrofit utility bills as shown in Table 18. To perform the appropriate weather normalization, ASHRAE's Inverse Model Toolkit (Kissock et al. 2002) is used to develop change-point linear models for both the pre-retrofit and post-retrofit period using daily average NOAA weather data from the nearest weather location (Figure 28). As shown in Figure 27, IMT then produces pre-retrofit and post-retrofit coefficients (Table 20) that are used to determine the annual energy use in 1999 and the 1999 peak day energy use for the Ozone Episode Day (August 19, 1999) as shown in Table 21 and Figure 29.

In the next step of the analysis and in a similar fashion to the analysis shown for the residential simulation (Figure 10), the emissions calculator calculates the NOx, SOx, and CO_2 using the USEPA's eGRID database. These results are then reported by the emissions calculator in a format that is similar to that shown in Table 10 for residential and are emailed to the user as HTML and XML files.

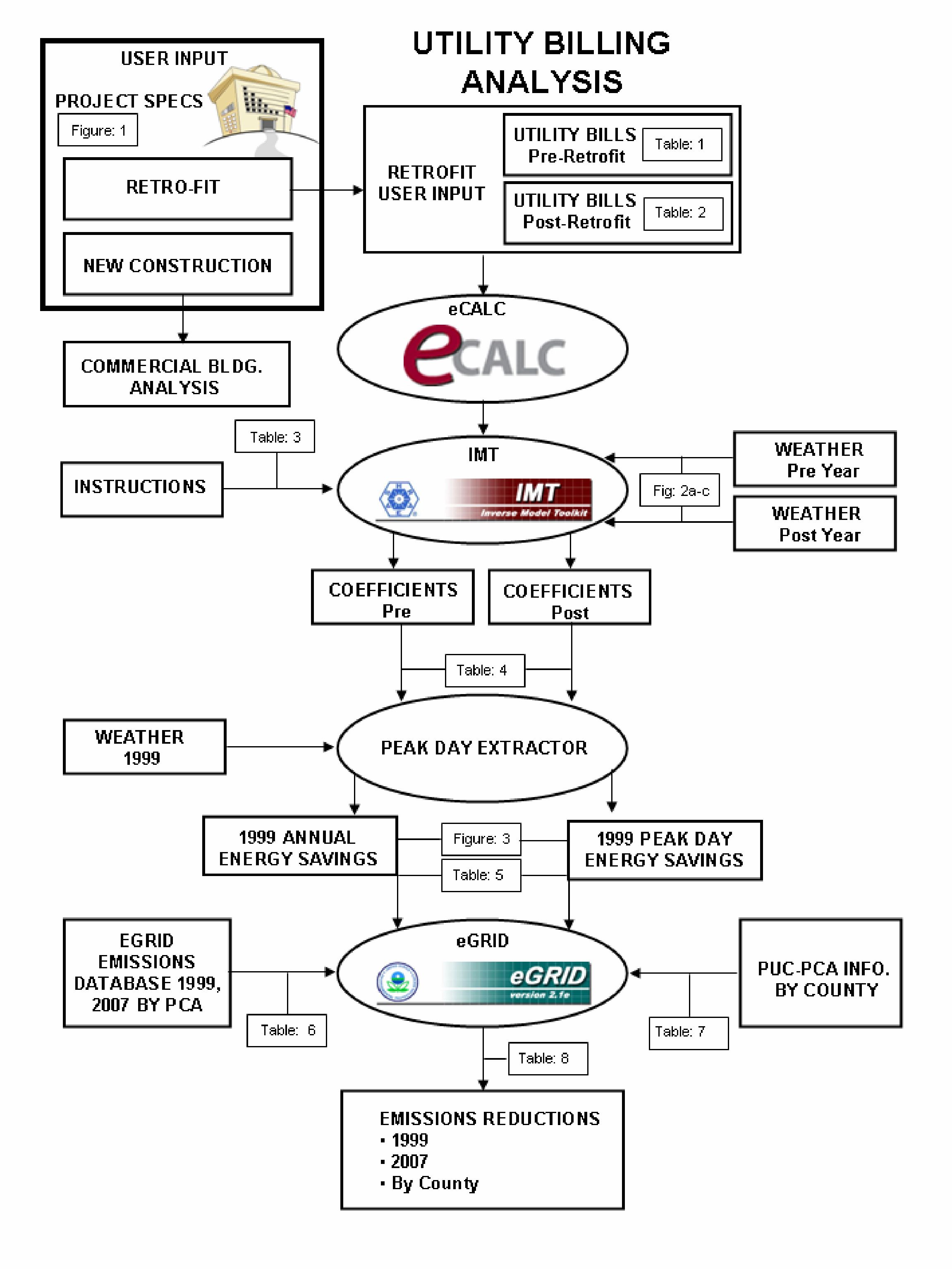


Figure 27: Municipal Building Retrofit Analysis Flowchart.

Pre-OE

Start Date	End Date	Days	Energy Usage	Usage Per Period	Avg Period Temp.
1/13/2000	2/13/2000	31	544.00	17.55	55.09
2/13/2000	3/12/2000	28	447.00	15.96	65.93
3/12/2000	4/10/2000	29	483.00	16.66	65.38
4/10/2000	5/10/2000	30	1020.00	34.00	73.80
5/10/2000	6/12/2000	33	1609.00	48.76	78.48
6/12/2000	7/9/2000	27	1530.00	56.67	83.11
7/9/2000	8/9/2000	31	1267.00	40.87	86.16
8/9/2000	9/12/2000	34	1619.00	47.62	87.29
9/12/2000	10/10/2000	28	1174.00	41.93	72.32
10/10/2000	11/9/2000	30	558.00	18.60	68.27
11/9/2000	12/10/2000	31	394.00	12.71	51.71
12/10/2000	12/31/2000	21	426.00	20.29	43.48

Table 1: Pre-Retrofit Sample Monthly Electricity Bills

Post-OE

Start Date	End Date	Days	Energy Usage	Usage Per Period	Avg Period Temp.
1/13/2001	2/13/2001	31	556.00	17.94	50.97
2/13/2001	3/12/2001	27	457.00	16.93	57.11
3/12/2001	4/10/2001	29	367.00	12.66	60.86
4/10/2001	5/10/2001	30	860.00	28.67	70.57
5/10/2001	6/12/2001	33	1599.00	48.45	78.00
6/12/2001	7/9/2001	27	1380.00	51.11	82.52
7/9/2001	8/9/2001	31	1033.00	33.32	87.65
8/9/2001	9/12/2001	34	1500.00	44.12	82.18
9/12/2001	10/10/2001	28	1103.00	39.39	73.18
10/10/2001	11/9/2001	30	510.00	17.00	66.90
11/9/2001	12/10/2001	31	270.00	8.71	59.55
12/10/2001	12/31/2001	21	410.00	19.52	50.38

Table 2:Post-Retrofit Sample Monthly Electricity Bills

Table 18: Municipal Building Retrofit Analysis Flowchart (Table 1 & 2 Pre and Post Utility Bills).

```
Path and name of input data file = dflt_fchart.prn
Value of no-data flag = -99
Column number of group field = 0
Value of valid group field = 1
Residual file needed (1 yes, 0 no) = 1
Model type (1:Mean,2:2p,3:3pc,4:3ph,5:4p,6:5p,7:MVR,8:HDD,9:CDD) = 4
Column number of dependent Y variable = 7
Number of independent X variables (0 to 6)  = 1
Column number of independent variable X1 = 1
Column number of independent variable X2 = 0
Column number of independent variable X3 = 0
Column number of independent variable X4 = 0
Column number of independent variable X5 = 0
Column number of independent variable X6 = 0
```

Table3: Example of I.M.T Input File

Table 19: Municipal Building Retrofit Analysis Flowchart (Table 3 – IMT Instructions File).

```
 ASHRAE INVERSE MODELING TOOLKIT (1.9)
********************************************
   Output file name = IMT.Out
********************************************
   Input data file name =  dflt_fchart.prn
   Model type =          4P
   Grouping column No =    0
   Value for grouping =    1
   Residual mode =         1
   # of X(Indep.) Var =    1
   Y1 column number =      2
   X1 column number =   1
   X2 column number =   0 (unused)
   X3 column number =   0 (unused)
   X4 column number =   0 (unused)
   X5 column number =   0 (unused)
   X6 column number =   0 (unused)
********************************************
   Regression Results
  --------------------------------------
          N =     12
  --------------------------------------
         R2 =     0.987
  --------------------------------------
      AdjR2 =     0.987
  --------------------------------------
       RMSE =      2.8479
  --------------------------------------
    CV-RMSE =     4.844%
  --------------------------------------
          p =     0.084
  --------------------------------------
         DW =     1.762 (p>0)
  --------------------------------------
         N1 =      8
  --------------------------------------
         N2 =      4
  --------------------------------------
        Ycp =     68.6995 (     10.3949)
  --------------------------------------
         LS =      1.6155 (      0.1069)
  --------------------------------------
         RS =      2.1659 (      0.3879)
  --------------------------------------
        Xcp =     74.3220 (      0.7060)
  --------------------------------------
```

Table 4: Example of I.M.T. Coefficients

Table 20: Municipal Building Retrofit Analysis Flowchart (Table 4 – IMT Output File).

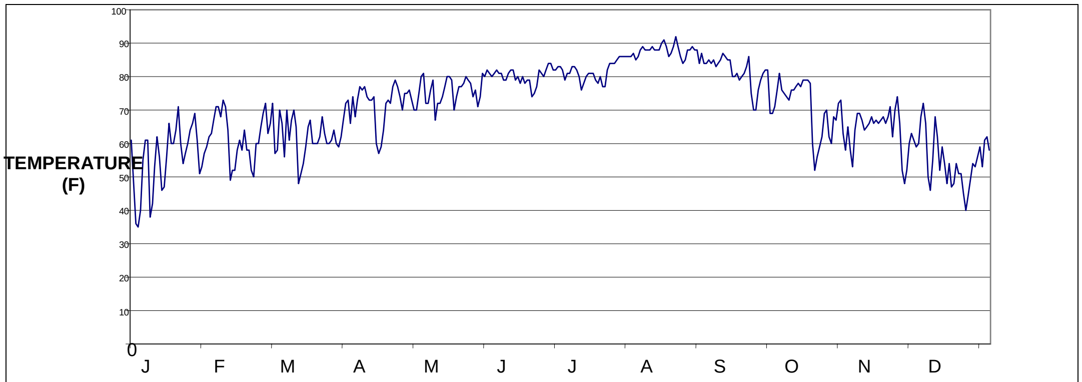


Figure 2a: Daily report of Dry Bulb Temperature for Austin, 1999

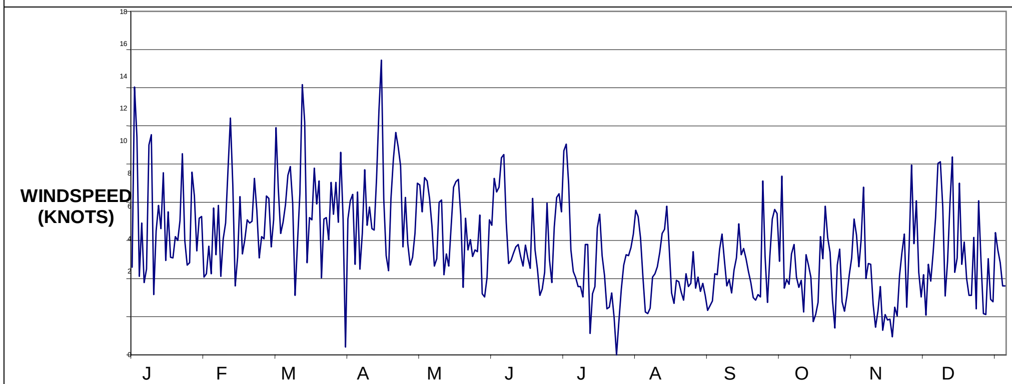


Figure 2b: Daily report of average wind speed for Austin, 1999

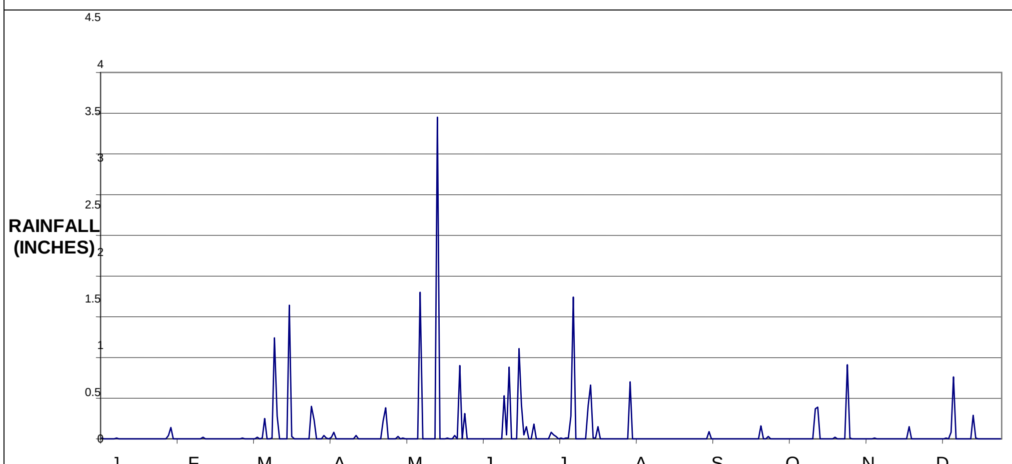
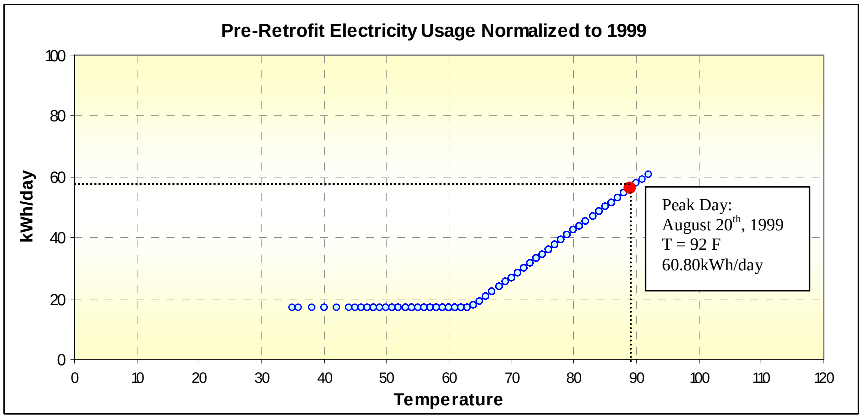


Figure 2c: Daily report of average precipitation for Austin, 1999

Figure 28: Municipal Building Retrofit Analysis Flowchart (Figures 2a-2c – 1999 Weather Data).



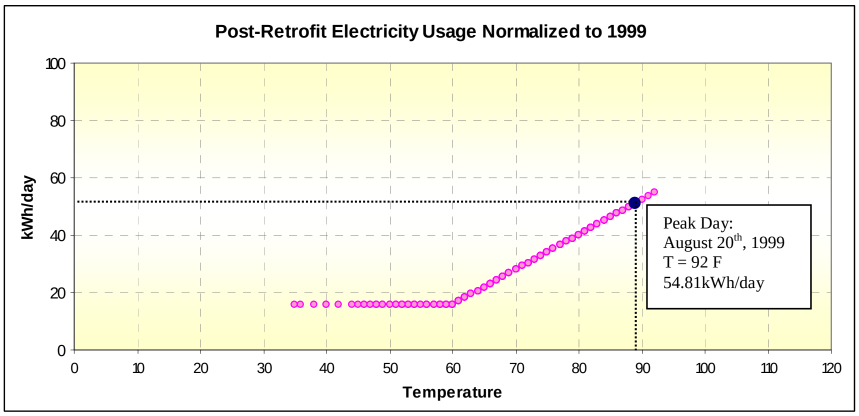


Fig 3: Examples of Peak outputs from Peak Day Extractor

Figure 29: Municipal Building Retrofit Analysis Flowchart (Figure 3 – Example Peak Day Extraction).

Energy Savings	Pre-Retrofit (kWh)	Post-Retrofit (kWh)
Annual Sum	11,479.48	11,081.39
OSD Peak	56.18	51.15
OSD Average	50.06	46.29

Table5: Examples of Energy Saving Outputs from Peak Day Extractor

Table 21: Municipal Building Retrofit Analysis Flowchart (Table 5 – Output From Peak Day Extractor).

2.3.2 Street Lights and Traffic Lights

2.3.2.1 Street Lights - New Construction Input Screens

The user input screens for new street light projects begin with the project input screen shown in Figure 30. When the user submits this type of project to the emissions calculator, they are directed to the screen shown in Figure 31. This input screen asks for specific information about the lamps in the project. For example, as shown in Figure 31 for the pre-retrofit mode, the user has specified that there are 12 mercury vapor lamps, type MV-100, that consume 100 Watts/lamp and produce 2,500 to 3,450 lumens/lamp, which use a photo cell on/off controller operating, on average, 12 hours per day in the first row. This type of lamp-by-lamp information is provided by the user for the pre-retrofit mode (Figure 31), and post-retrofit mode (Figure 32).

After entering this information for both pre-retrofit and post-retrofit modes, the user then submits the information to the emissions calculator by pressing the "calculate" button. The emissions calculator then calculates the annual and peak-day savings and emails the results to the user.

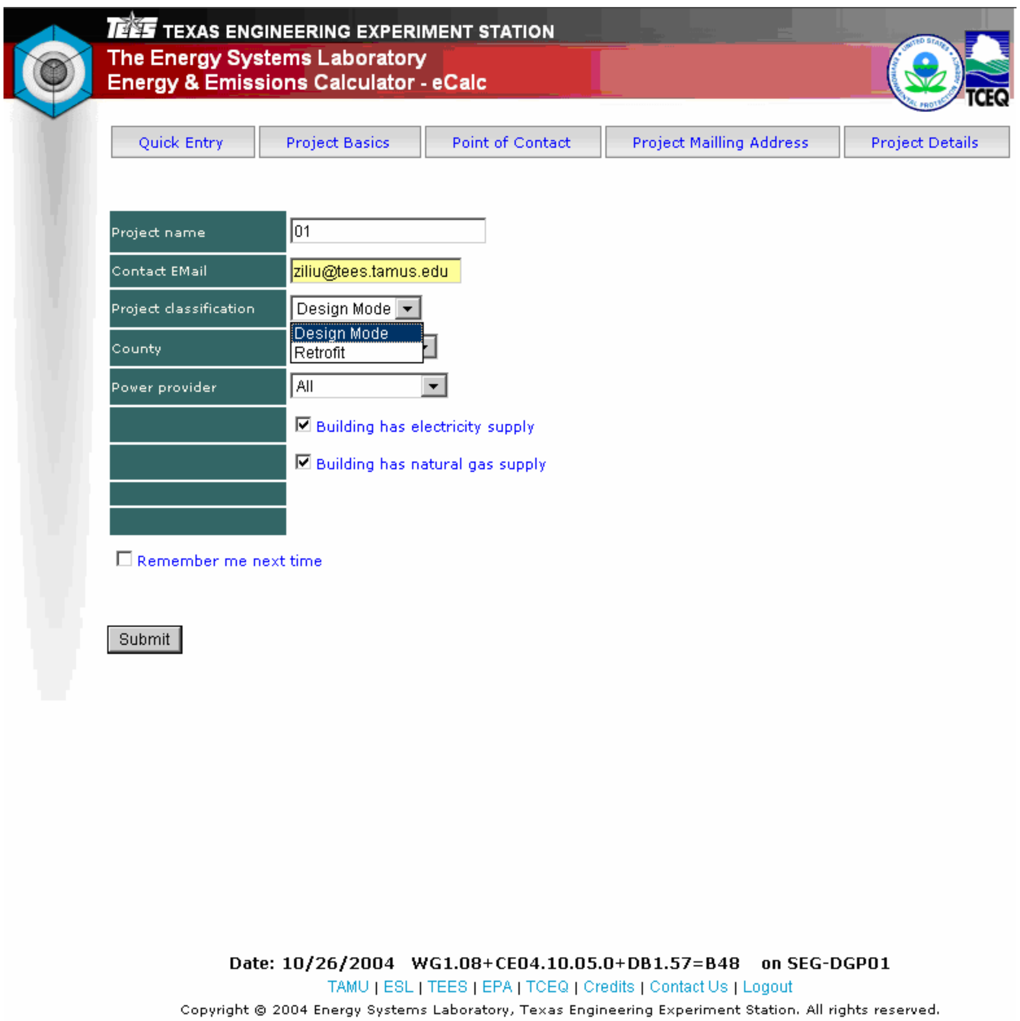


Figure 30: Street Lights - New Construction Input Screens (Project Info).

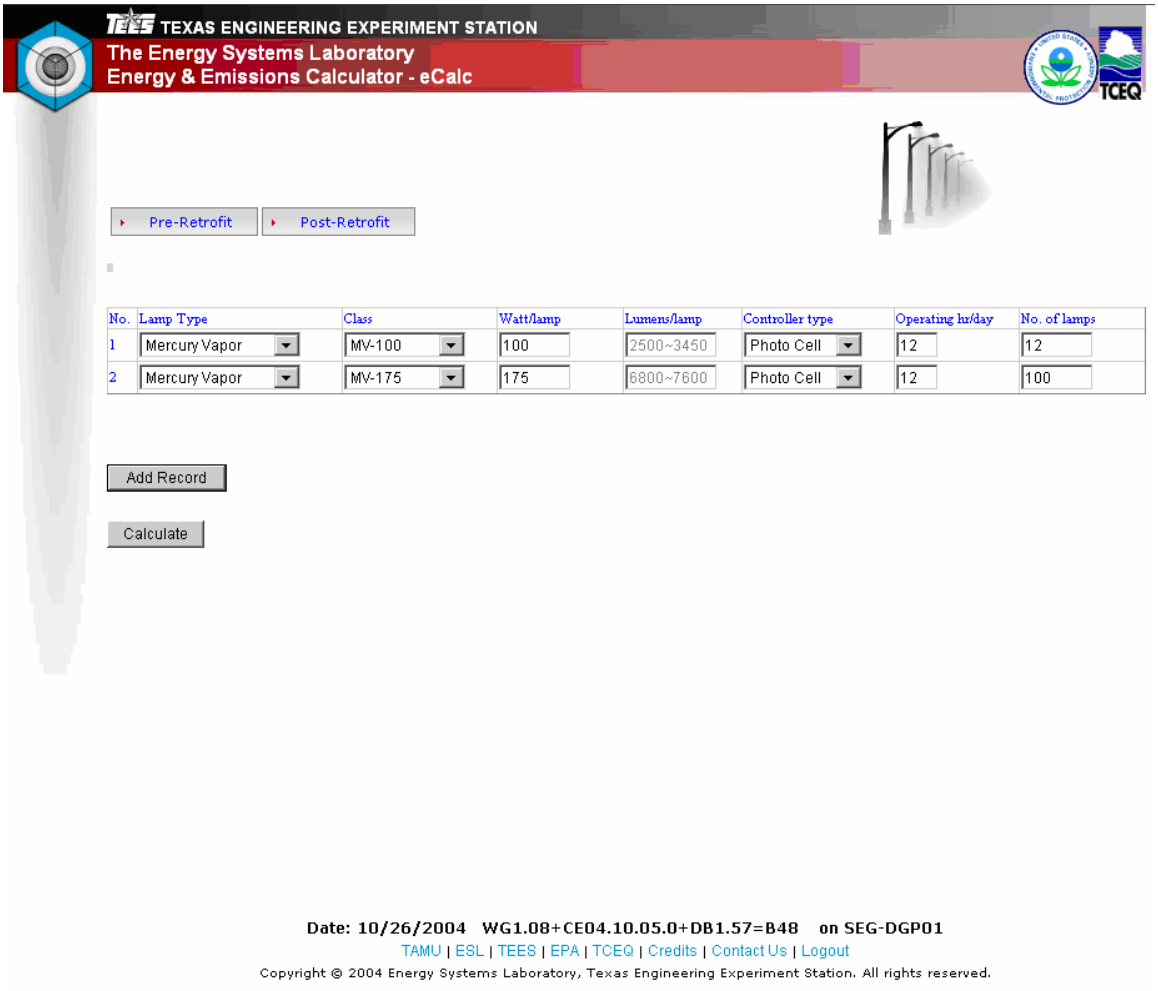


Figure 31: Street Lights - New Construction Input Screens (Pre-retrofit Lamp Info).

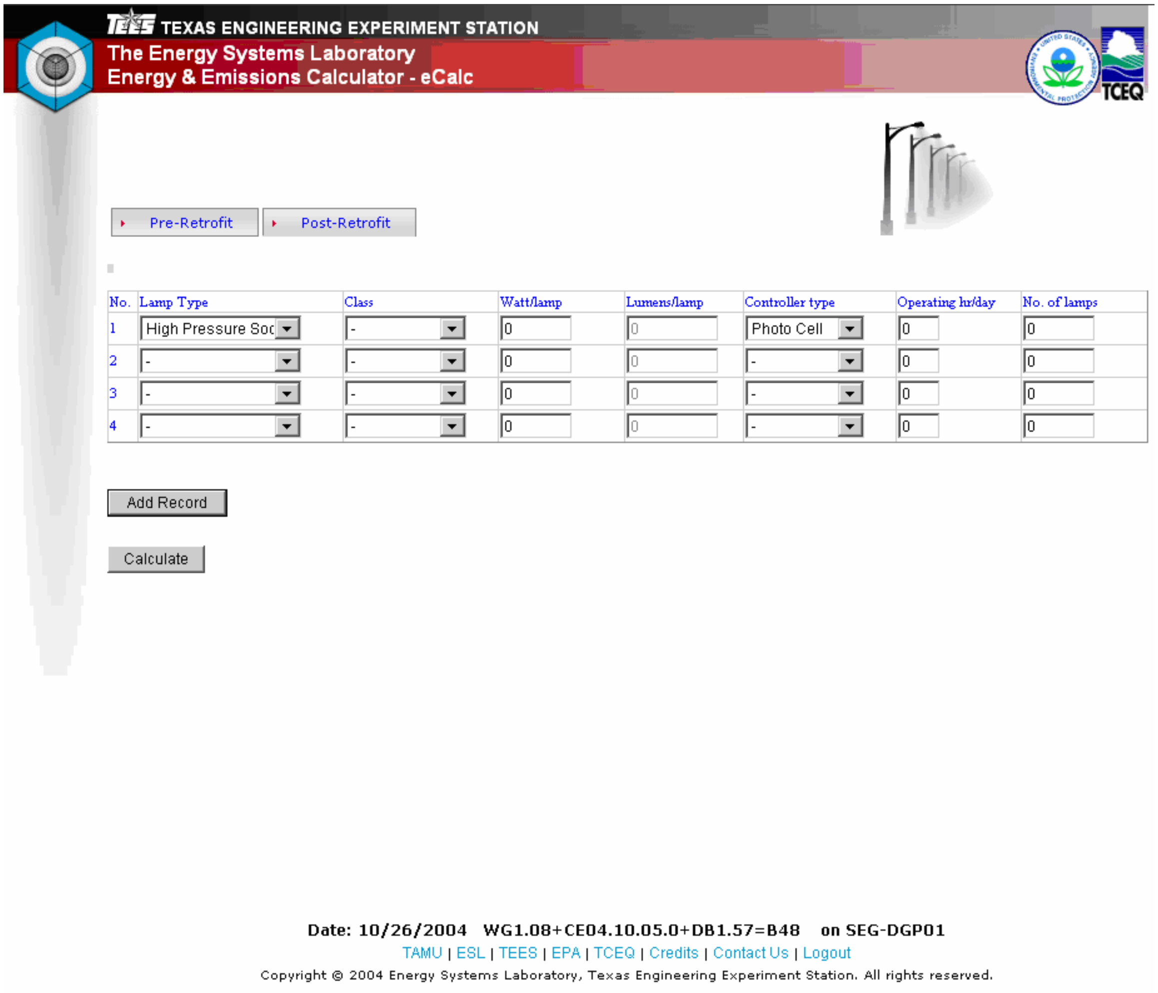


Figure 32: Street Lights - New Construction Input Screens (Post-retrofit Lamp Info).

2.3.2.2 Traffic Lights - New Construction Input Screens

The user input screens for new traffic light projects begin with the project input screen shown in Figure 33. When the user submits this type of project to the emissions calculator, they are directed to the screen shown in Figure 34. This input screen asks for specific information about the lamps in the project. For example, as shown in Figure 34 for the pre-retrofit mode, the user has specified green ball, green arrow, red ball, yellow arrow, yellow ball, and pedestrian type lamps. This type of lamp-by-lamp information is provided by the user for the pre-retrofit mode (Figure 34) and post-retrofit mode (Figure 35).

After entering this information for both pre-retrofit and post-retrofit modes, the user then submits the information to the emissions calculator by pressing the “calculate” button. The emissions calculator then calculates the annual and peak-day savings and emails the results to the user.

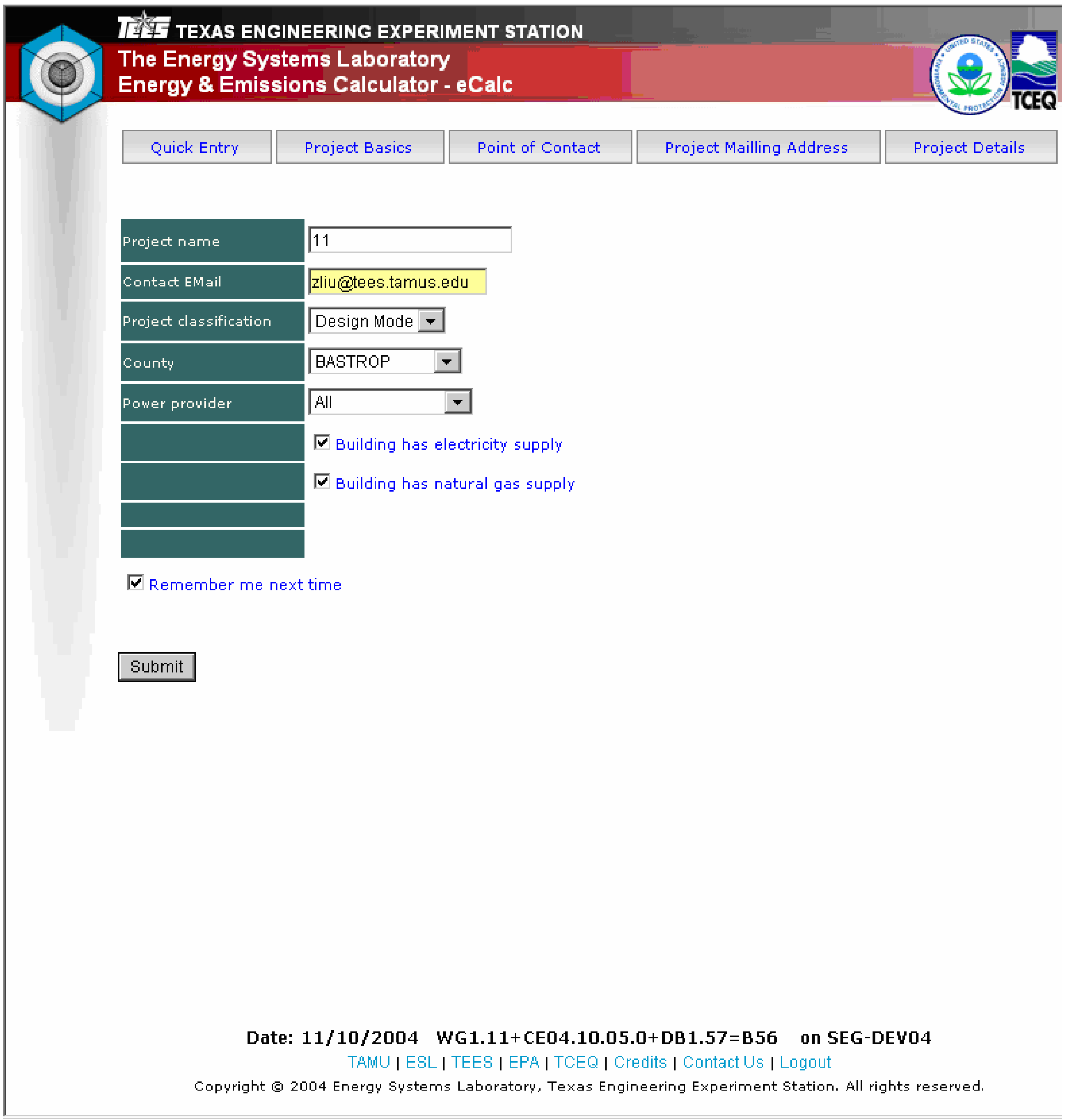
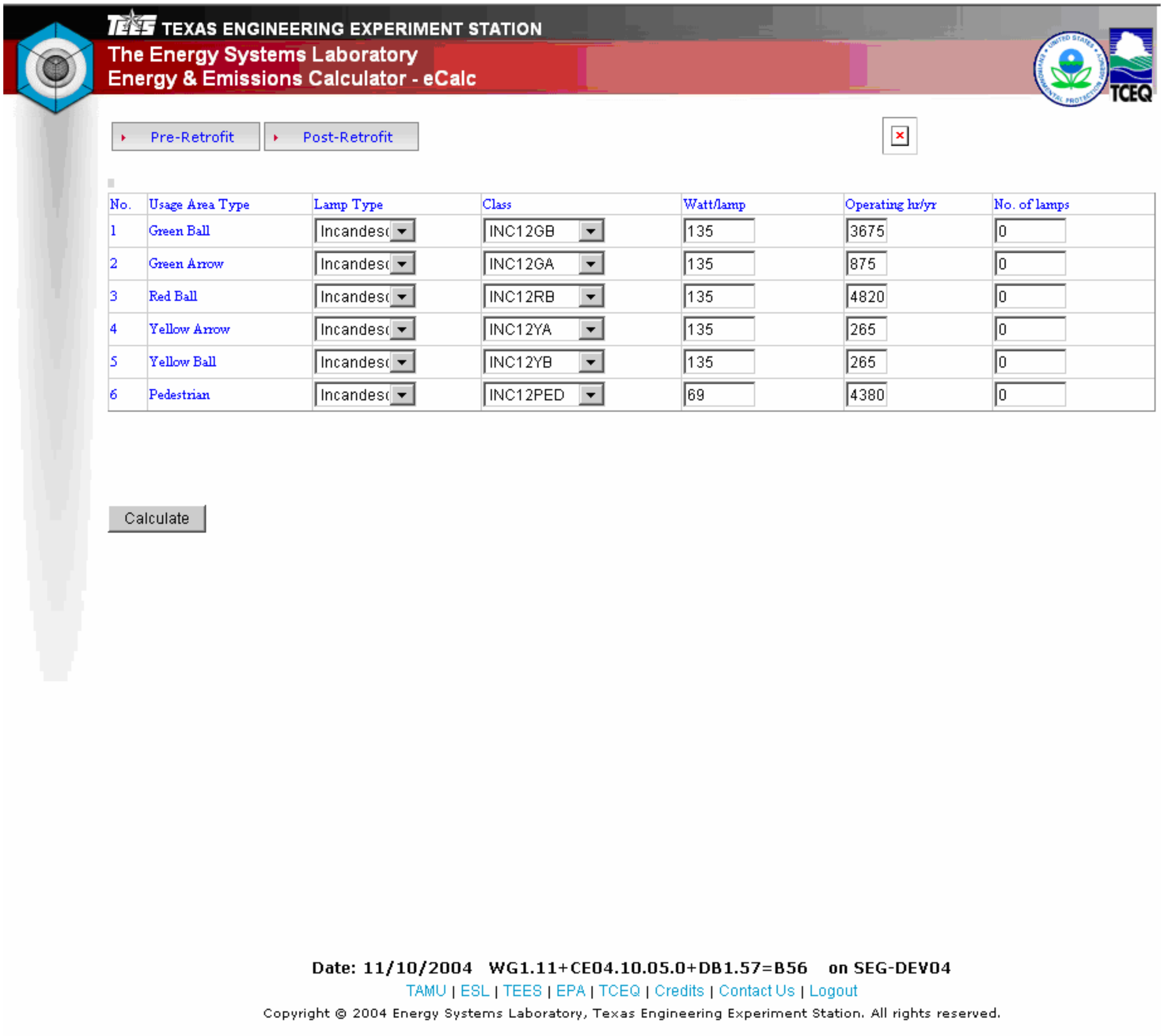


Figure 33: Traffic Lights - New Construction Input Screens (Project Info).



No.	Usage Area Type	Lamp Type	Class	Watt/lamp	Operating hr/yr	No. of lamps
1	Green Ball	Incandesc	INC12GB	135	3675	0
2	Green Arrow	Incandesc	INC12GA	135	875	0
3	Red Ball	Incandesc	INC12RB	135	4820	0
4	Yellow Arrow	Incandesc	INC12YA	135	265	0
5	Yellow Ball	Incandesc	INC12YB	135	265	0
6	Pedestrian	Incandesc	INC12PED	69	4380	0

Figure 34: Traffic Lights - New Construction Input Screens (Pre-retrofit Lamp Info).

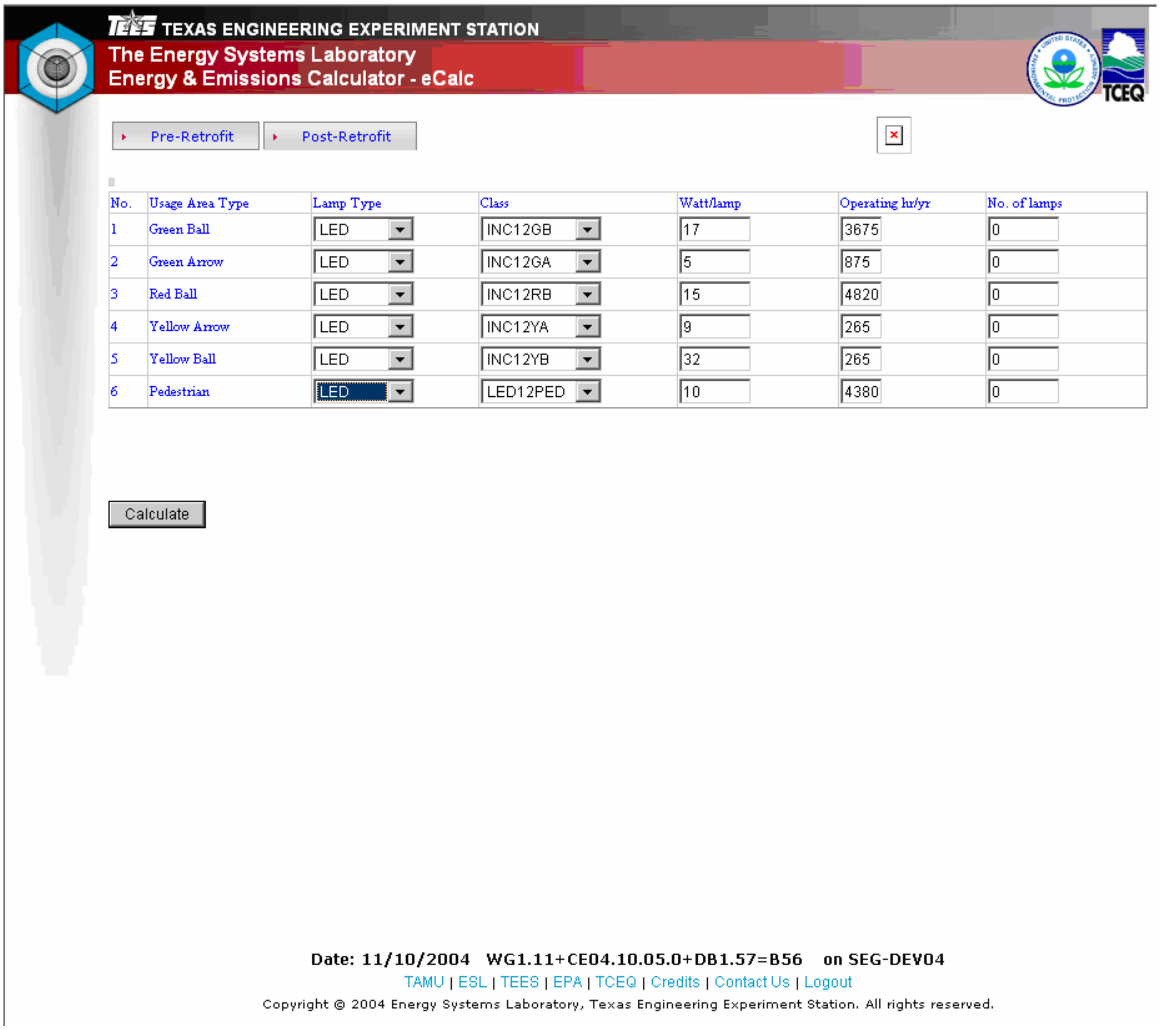


Figure 35: Traffic Lights - New Construction Input Screens (Post-retrofit Lamp Info).

2.3.2.3 Street Lights and Traffic Lights - New Construction Analysis Description

When the user submits their street light or traffic light analysis for a new construction project, the emissions calculator compares the pre-retrofit electricity use for the pre-retrofit lamps specified against the electricity use calculated for the post-retrofit lamps specified for the same operating hours as shown in Table 22 (Pre-retrofit lamp example) and Table 23 (Post-retrofit lamp example). The emissions calculator then calculates the annual and peak-day savings, as shown in Table 24 and Figure 37, using ASHRAE's Inverse Model Toolkit (Kissock et al. 2002) to calculate a linear model of the the peak-day energy use for both the pre-retrofit and post-retrofit period using daily average NOAA weather data from the nearest weather location.

In the next step of the analysis and in a similar fashion to the analysis shown for the residential simulation (Figure 10), the emissions calculator calculates the NOx, SOx, and CO_2 using the USEPA's eGRID database. These results are then reported by the emissions calculator in a format that is similar to that shown in Table 10 for residential and then emailed to the user as HTML and XML files.

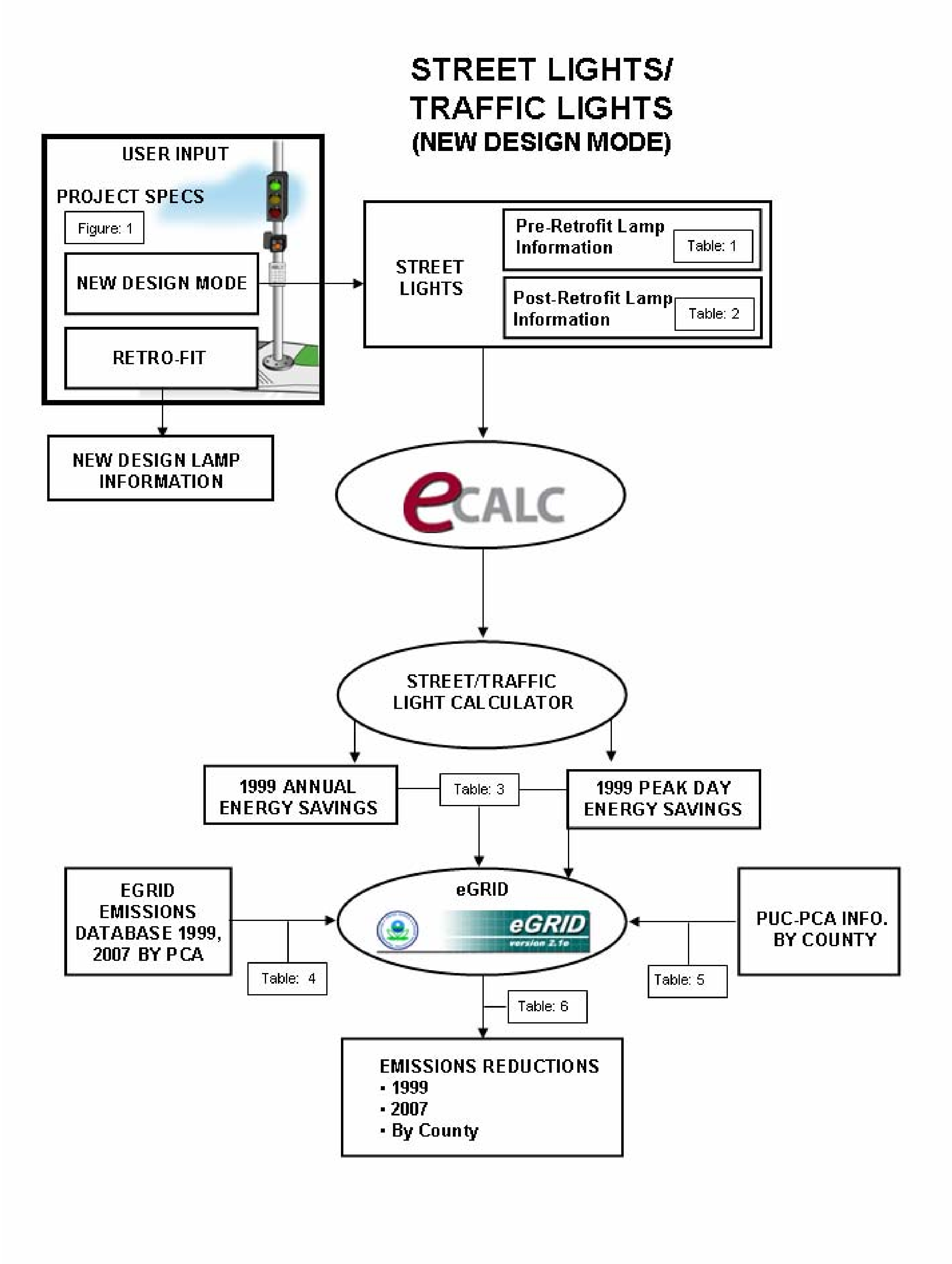


Figure 36: Street Lights & Traffic Lights – New Design Mode Analysis Flowchart.

Pre-Retrofit:							
Project No.	Type of Lamp[1]	Class[2]	Watt/Lamp	Approximate Lumens/Lamp	Controller Type[3]	Operating Hours Per Day	Number of Lamps
1	Mercury Vapor	MV-400	400	13400~19100	Photocell	12	100
2	Mercury Vapor	MV-175	175	6800~7600	Photocell	12	50
	-	-	-	-	-	-	
	-	-	-	-	-	-	
	-	-	-	-	-	-	
	-	-	-	-	-	-	
	-	-	-	-	-	-	
	-	-	-	-	-	-	
	-	-	-	-	-	-	
	-	-	-	-	-	-	

Table 1: Pre-Retrofit Lamp Information

Table 22: Street Lights & Traffic Lights – New Design Mode Analysis Flowchart (Table 1: Pre-Retrofit Lamp Info).

Post-Retrofit:							
Project No.	Type of Lamp	Class	Watt/Lamp[4]	Approximate Lumens/Lamp[5]	Controller Type[6]	Operating Hours Per Day[7]	Number of Lamps[8]
1	High Pressure Sodium	HPS-200	200	19800	Photocell	12	100
2	High Pressure Sodium	HPS-100	100	8000	Photocell	12	50
	-	-	-	-	-	-	0
	-	-	-	-	-	-	0
	-	-	-	-	-	-	0
	-	-	-	-	-	-	0
	-	-	-	-	-	-	0
	-	-	-	-	-	-	0
	-	-	-	-	-	-	0
	-	-	-	-	-	-	0

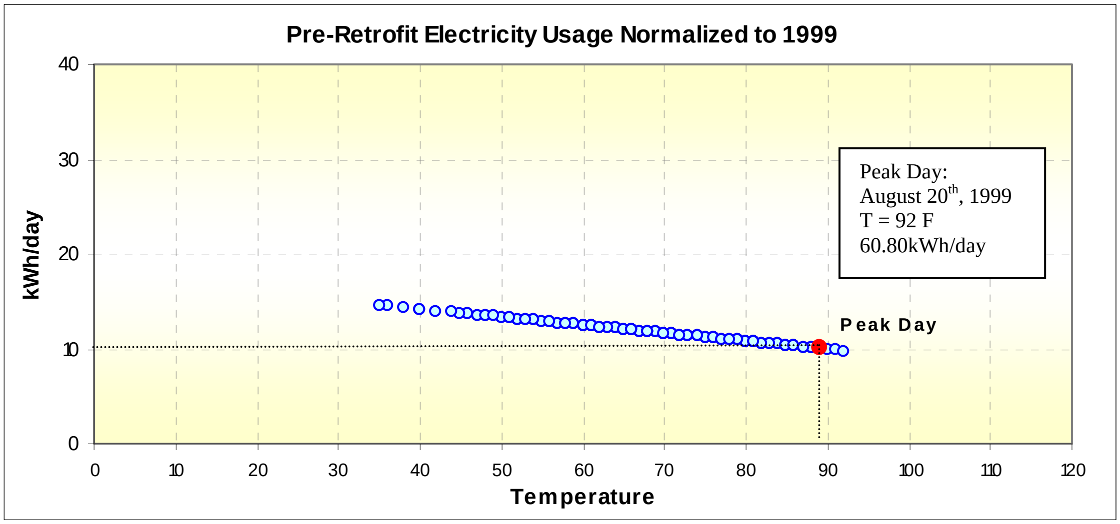
Table 2: Post-Retrofit Lamp Information

Table 23: Street Lights & Traffic Lights – New Design Mode Analysis Flowchart (Table 2: Post-Retrofit Lamp Info).

Project No.	Lighting Energy Savings (kWh/yr)	Peak Day (Aug 19 1999) Savings (kWh/day)	Avg OSD Savings (kWh/day)
1	91980.00	231.14	240.93
2	14563.50	41.96	43.74
Total	**106543.50**	**273.10**	**284.67**

Table 3: Examples of Annual and Peak Energy Savings for Street Light Calculator.

Table 24: Street Lights & Traffic Lights – New Design Mode Analysis Flowchart (Table 3: Examples of Annual and Peak Energy Savings for Street Light Calculations).



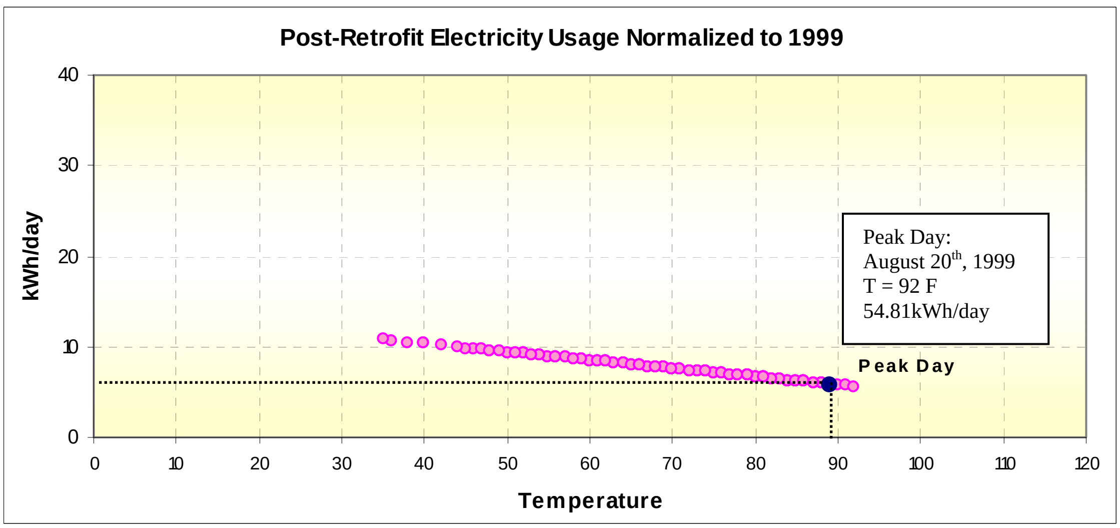


Fig 3: Examples of Peak outputs from Peak Day Extractor.

Figure 37: Street Lights & Traffic Lights – New Design Mode Analysis Flowchart (Figure 3: Examples of Peak Energy Savings for Street Light Calculations).

2.3.2.4 Street Lights and Traffic Lights - Retrofit Input Screens

The user input screens for street light and traffic light retrofit projects begin with a similar project input screen as seen in the other projects shown in Figure 38. When the user submits this type of project to the emissions calculator they are directed to the screen shown in Figure 39. This screen asks for the beginning dates for the 12 months of pre-retrofit data and for the retrofit. After entering this information, the user can then begin entering the pre-retrofit and post-retrofit data into the screen shown in Figure 40. When the user completes entering 12 months of both the pre-retrofit and post-retrofit data, they press the "done with both bills" button and the project is submitted for analysis.

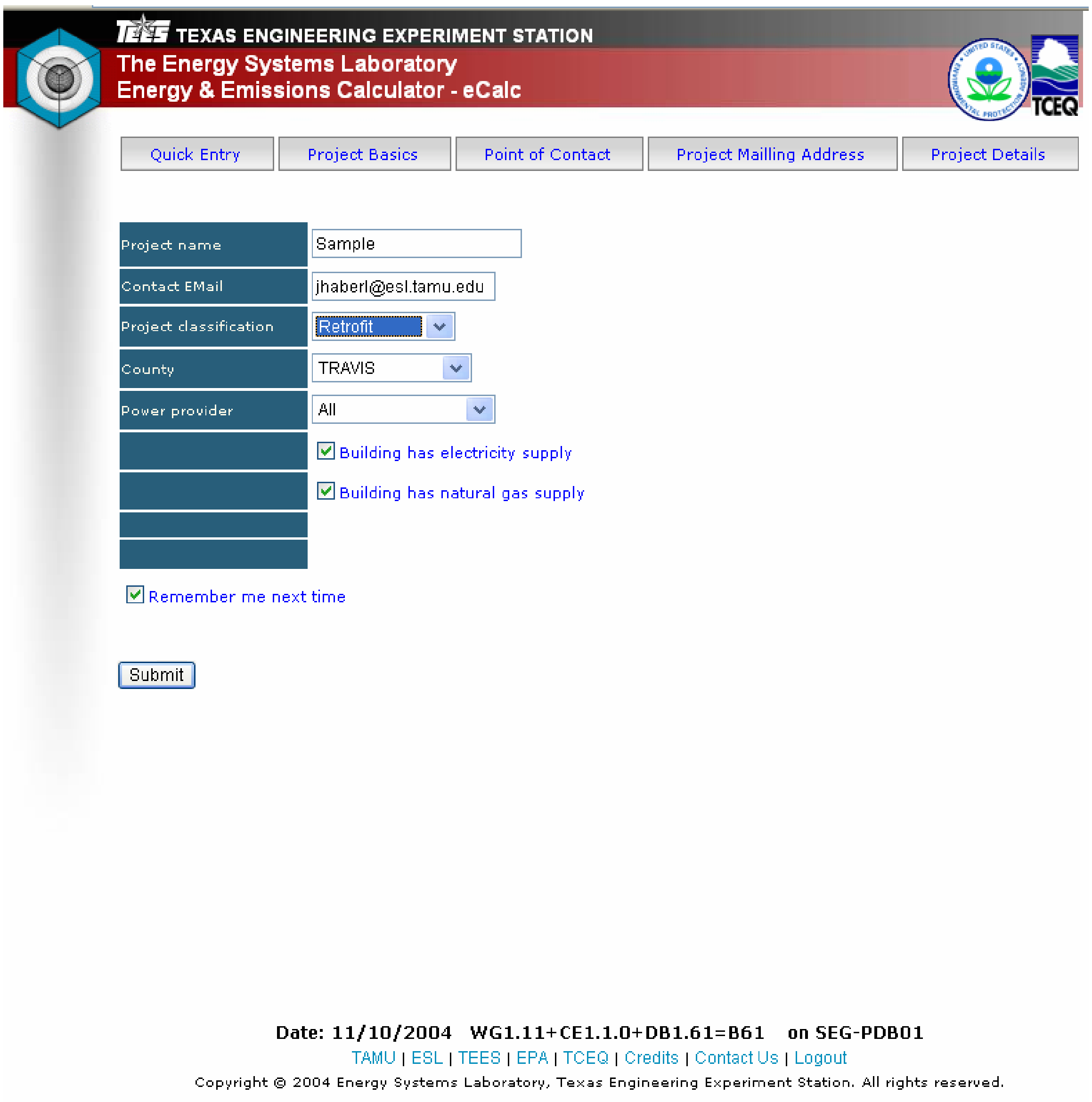


Figure 38: Street Lights and Traffic Lights Retrofit Project Data Entry Screen (Project Input).

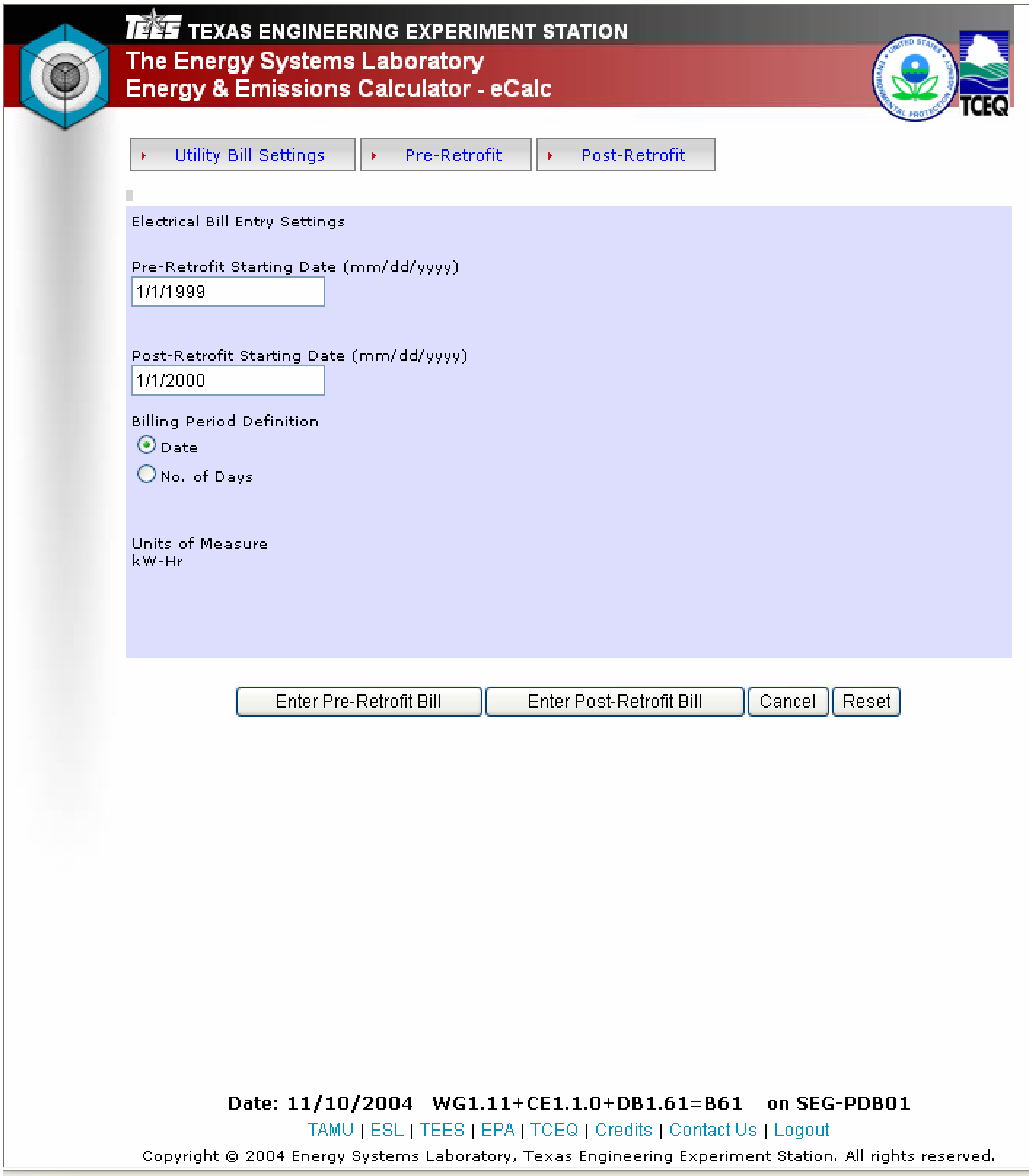


Figure 39: Street Lights and Traffic Lights Retrofit Project Data Entry Screen (Project Pre and Post Dates).

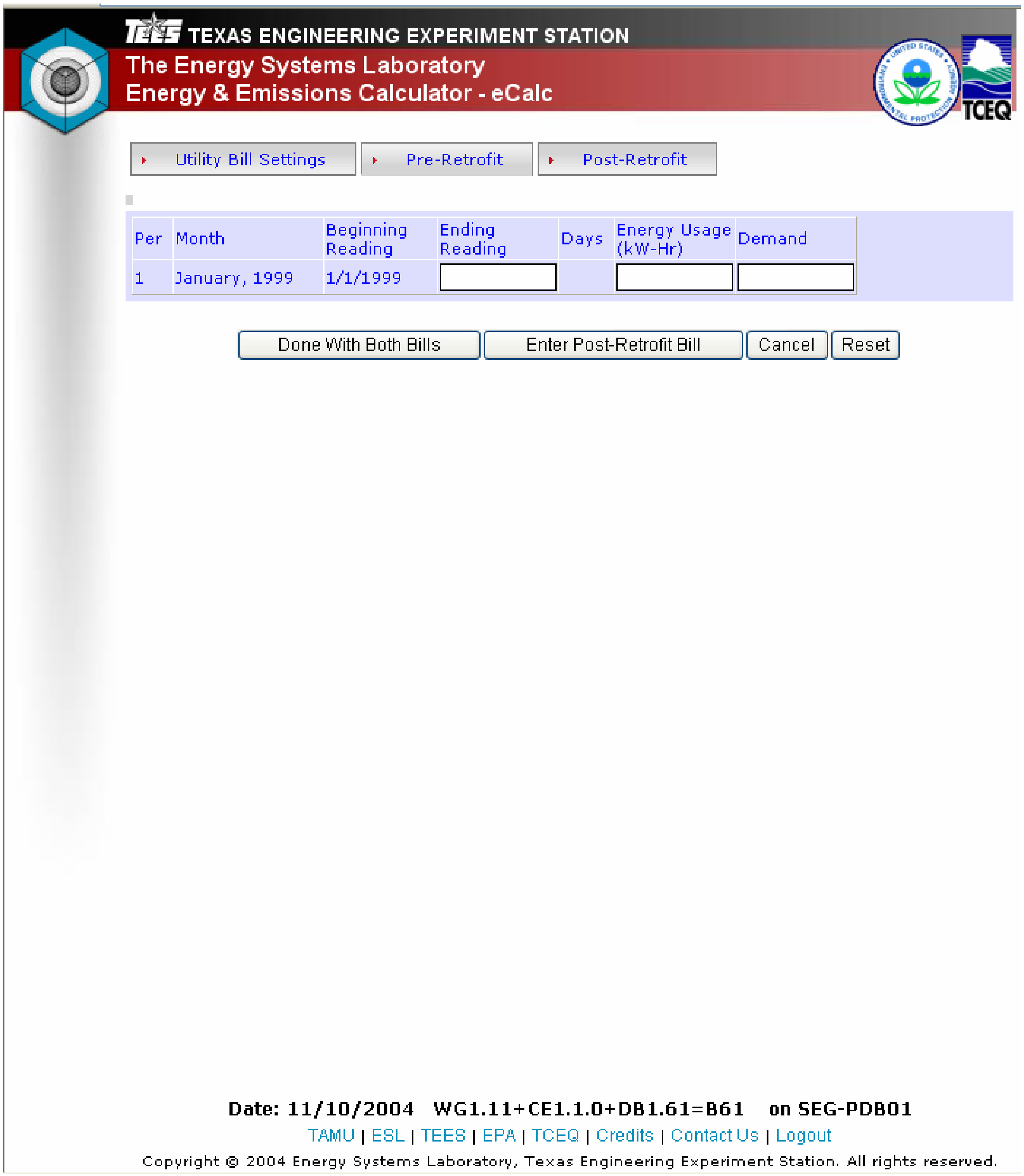


Figure 40: Street Lights and Traffic Lights Retrofit Project Data Entry Screen (Pre and Post Utility Bill Input).

2.3.2.5 Street Lights and Traffic Lights- Retrofit Analysis Description

When the user submits their street light or traffic light retrofit project for analysis, the emissions calculator performs a series of calculations, as indicated in Figure 41. For each analysis, the user is required to enter 12 pre-retrofit utility bills and 12 post-retrofit utility bills as shown in Table 25. In cases where weather normalization is needed, ASHRAE's Inverse Model Toolkit (Kissock et al. 2002) is used to develop linear models for both the pre-retrofit and post-retrofit period using daily average NOAA weather data from the nearest weather location (Figure 42). As shown in Figure 41, IMT then produces pre-retrofit and post-retrofit coefficients (Table 27) that are used to determine the annual energy use in 1999 and the 1999 peak day energy use for the Ozone Episode Day (August 19, 1999), as shown in Table 28 and Figure 43.

In the next step of the analysis and in a similar fashion to the analysis shown for the residential simulation (Figure 10), the emissions calculator calculates the NOx, SOx, and CO_2 using the USEPA's eGRID database. These results are then reported by the emissions calculator in a format that is similar to that shown in Table 10 for residential and then emailed to the user as HTML and XML files.

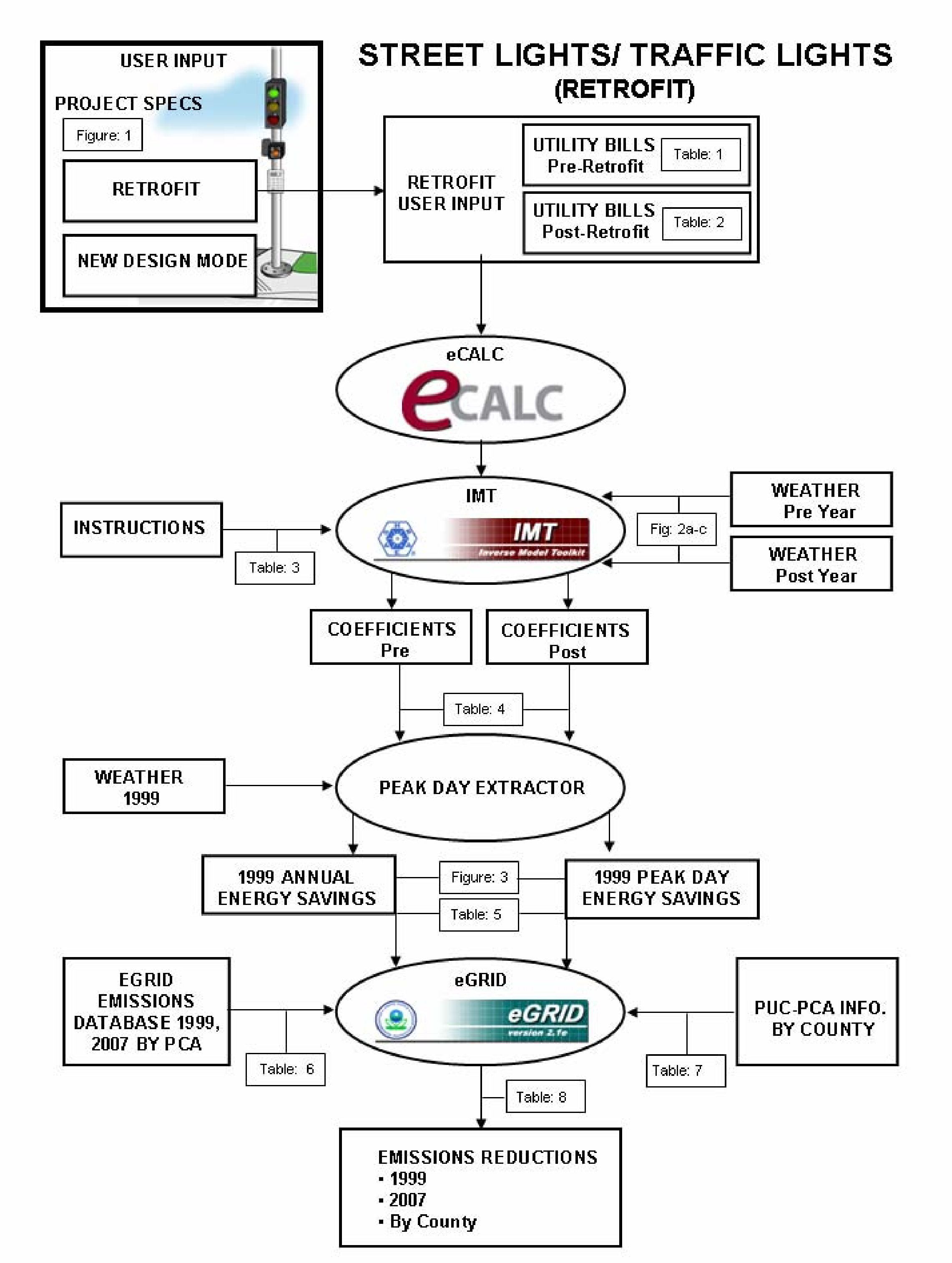


Figure 41: Street Lights & Traffic Lights – Retrofit Analysis Flowchart.

Pre-Retrofit Make-Up Bills					2000
Periods	Year	No. of Days	Avg. DB	Pre-Usage	Make-up Bills
1	2000	31	***55.09***	12.88	**399.39**
2	2000	28	***65.93***	11.97	**335.18**
3	2000	29	***65.38***	12.02	**348.50**
4	2000	30	***73.80***	11.31	**339.24**
5	2000	33	***78.48***	10.91	**360.16**
6	2000	27	***83.11***	10.52	**284.15**
7	2000	31	***86.16***	10.27	**318.29**
8	2000	34	***87.29***	10.17	**345.86**
9	2000	28	***72.32***	11.43	**320.12**
10	2000	30	***68.27***	11.77	**353.21**
11	2000	31	***51.71***	13.17	**408.21**
12	2000	21	***43.48***	13.86	**291.08**
					4103.40

Table 1: Pre-Retrofit Sample Monthly Electricity Bills.

Post-Retrofit Make-Up Bills					2001
Month	Year	No. of Days	Avg. DB	Pre-Usage	Make-up Bills
1	2001	31	***50.97***	9.29	287.88
2	2001	27	***57.11***	8.73	235.72
3	2001	29	***60.86***	8.39	243.32
4	2001	30	***70.57***	7.51	225.32
5	2001	33	***78.00***	6.84	225.64
6	2001	27	***82.52***	6.43	173.56
7	2001	31	***87.65***	5.96	184.86
8	2001	34	***82.18***	6.46	219.60
9	2001	28	***73.18***	7.27	203.68
10	2001	30	***66.90***	7.84	235.30
11	2001	31	***59.55***	8.51	263.78
12	2001	21	***50.38***	9.34	196.14
					2694.81

Table 2:Post-Retrofit Sample Monthly Electricity Bills.

Table 25: Street Lights & Traffic Lights – Retrofit Analysis Flowchart (Table 1 & 2: Pre and Post-retrofit Utility Bills).

Line 1: Path and name of input data file =StreetUB1.dat
Line 2: Value of no-data flag = -99
Line 3: Column number of group field = 0
Line 4: Value of valid group field = 0
Line 5: Residual file needed (1 yes, 0 no) = 1
Line 6: Model (1:Mean,2:2p,3:3pc,4:3ph,5:4p,6:5p,7:MVR,8:HDD,9:CDD) = 9
Line 7: Column number of dependent variable Y = 4
Line 8: Number of independent variables (0 to 6) = 1
Line 9: Column number of independent variable X1 = 5
Line 10: Column number of independent variable X2 = 0
Line 11: Column number of independent variable X3 = 0
Line 12: Column number of independent variable X4 = 0
Line 13: Column number of independent variable X5 = 0
Line 14: Column number of independent variable X6 = 0

Table3: Example of IMT Input File.

Table 26: Street Lights & Traffic Lights – Retrofit Analysis Flowchart (Table 3: Example IMT Input File).

```
********************************************
  ASHRAE INVERSE MODELING TOOLKIT (1.9)

********************************************
    Output file name = IMT.Out

********************************************
    Input data file name =  StreetUB1_R.RES
    Model type =           2P
    Grouping column No =    0
    Value for grouping =    0
    Residual mode =         0
    # of X(Indep.) Var =    1
    Y1 column number =      4
    X1 column number =   5
    X2 column number =   0 (unused)
    X3 column number =   0 (unused)
    X4 column number =   0 (unused)
    X5 column number =   0 (unused)
    X6 column number =   0 (unused)

********************************************
    Regression Results
   --------------------------------------
           N =     12
   --------------------------------------
          R2 =     0.652
   --------------------------------------
       AdjR2 =     0.652
   --------------------------------------
        RMSE =      0.8958
   --------------------------------------
     CV-RMSE =     7.661%
   --------------------------------------
           p =     0.322
   --------------------------------------
          DW =     1.325 (p>0)
   --------------------------------------
           a =     17.5221 (      1.3725)
   --------------------------------------
          X1 =     -0.0842 (      0.0195)
   --------------------------------------
```

Table4: Example of I.M.T Coefficients

Table 27: Street Lights & Traffic Lights – Retrofit Analysis Flowchart (Table 4: Example IMT Coefficients).

Energy Savings	Pre-Retrofit (kWh)	Post-Retrofit (kWh)
Annual Sum	11,479.48	11,081.39
OSD Peak	56.18	51.15
OSD Average	50.06	46.29

Table5: Examples of Energy Saving Outputs from Peak Day Extractor

Table 28: Street Lights & Traffic Lights – Retrofit Analysis Flowchart (Table 5: Example Output from Peak Day Extractor).

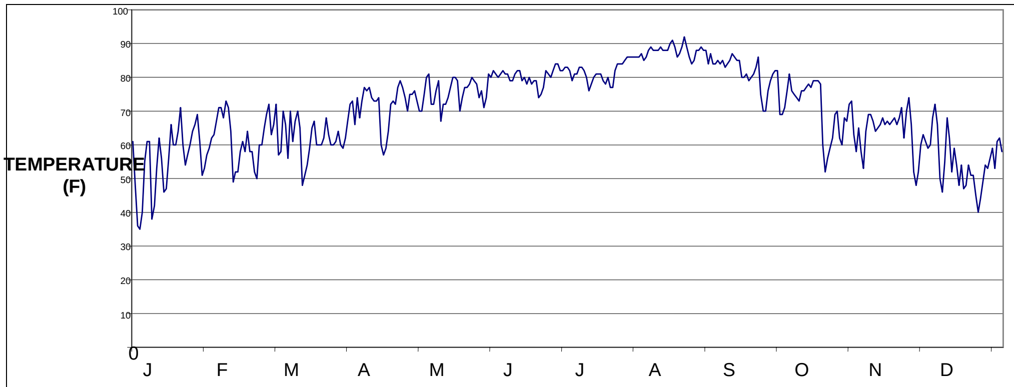


Figure 2a: Daily report of Dry Bulb Temperature for Austin, 1999

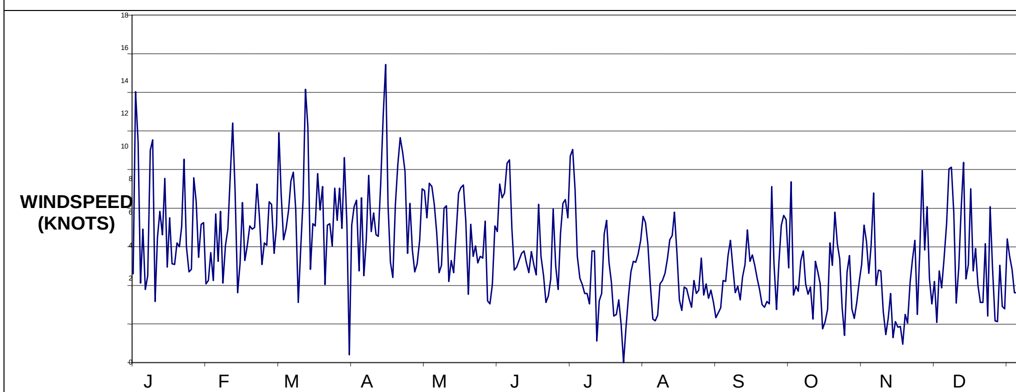


Figure 2b: Daily report of average wind speed for Austin, 1999

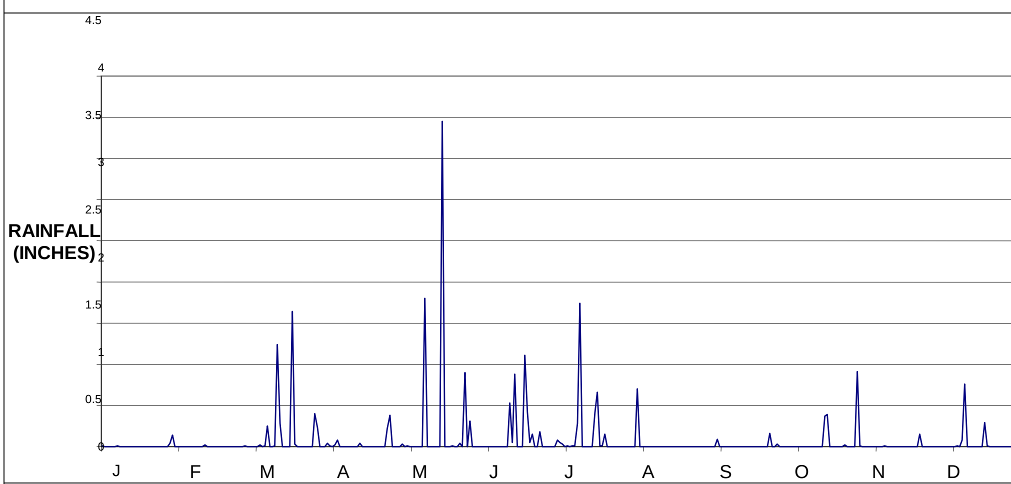
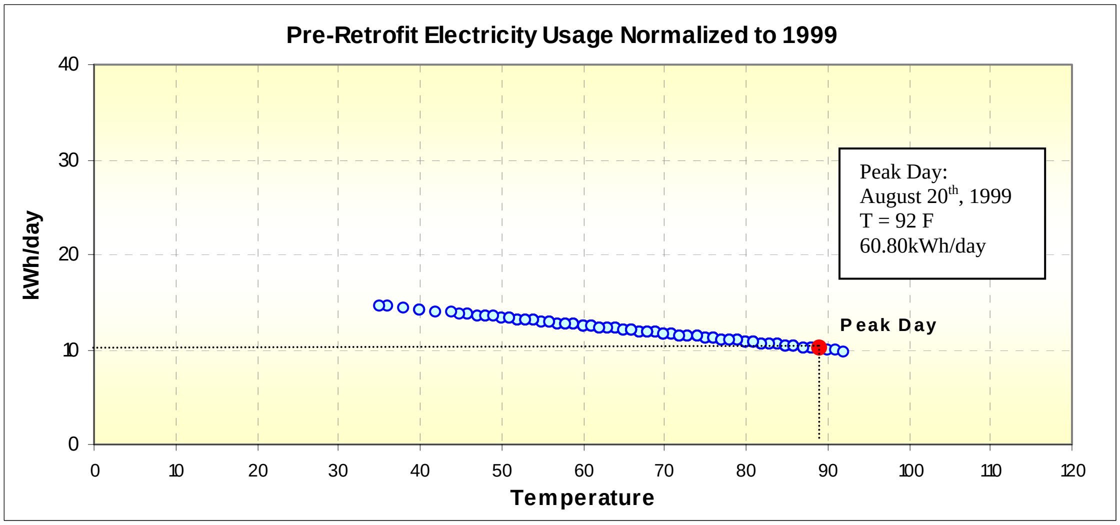


Figure 2c: Daily report of average precipitation for Austin, 1999

Figure 42: Street Lights & Traffic Lights – Retrofit Analysis Flowchart (Figure 2a-c: 1999 Daily Weather Data).



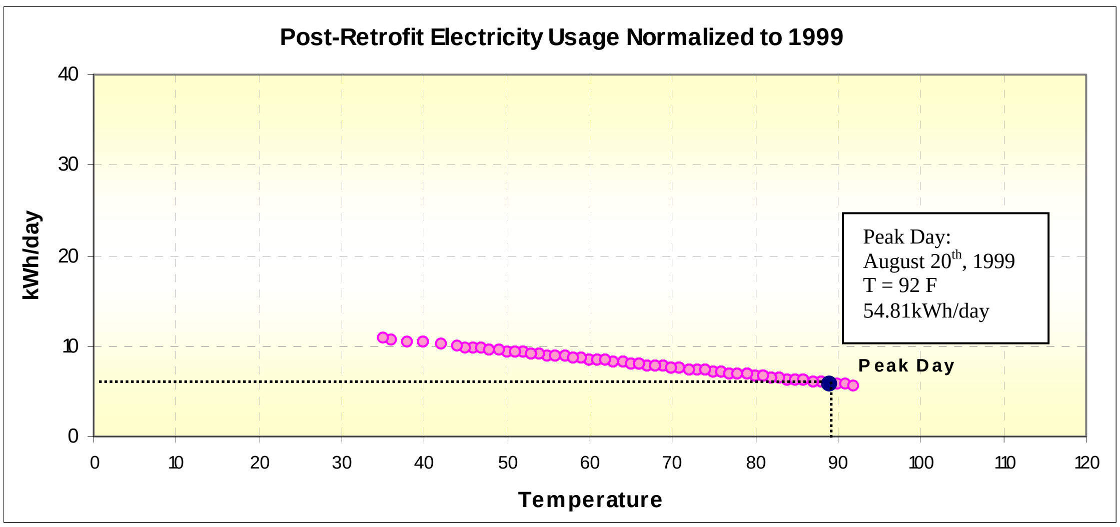


Fig 3: Examples of Peak outputs from Peak Day Extractor.

Figure 43: Street Lights & Traffic Lights – Retrofit Analysis Flowchart (Figure 3: Example peak-day output from peak-day extractor).

2.3.3 Municipal Water and Waste Water Supply Input Screens

The user input screens for municipal water and waste water retrofit projects begin with the same project input screen previously seen for the other projects as shown in Figure 44. When the user submits this type of project to the emissions calculator they are directed to the screen shown in Figure 45. This input screen asks for specific information about the beginning dates for the 12 months of pre-retrofit data and for the retrofit.

After entering this information, the user can then begin entering the pre-retrofit and post-retrofit data into the screen shown in Figure 46. When the user completes entering 12 months of both the pre-retrofit and post-retrofit data, they press the “done with both bills” button and the project is submitted for analysis.

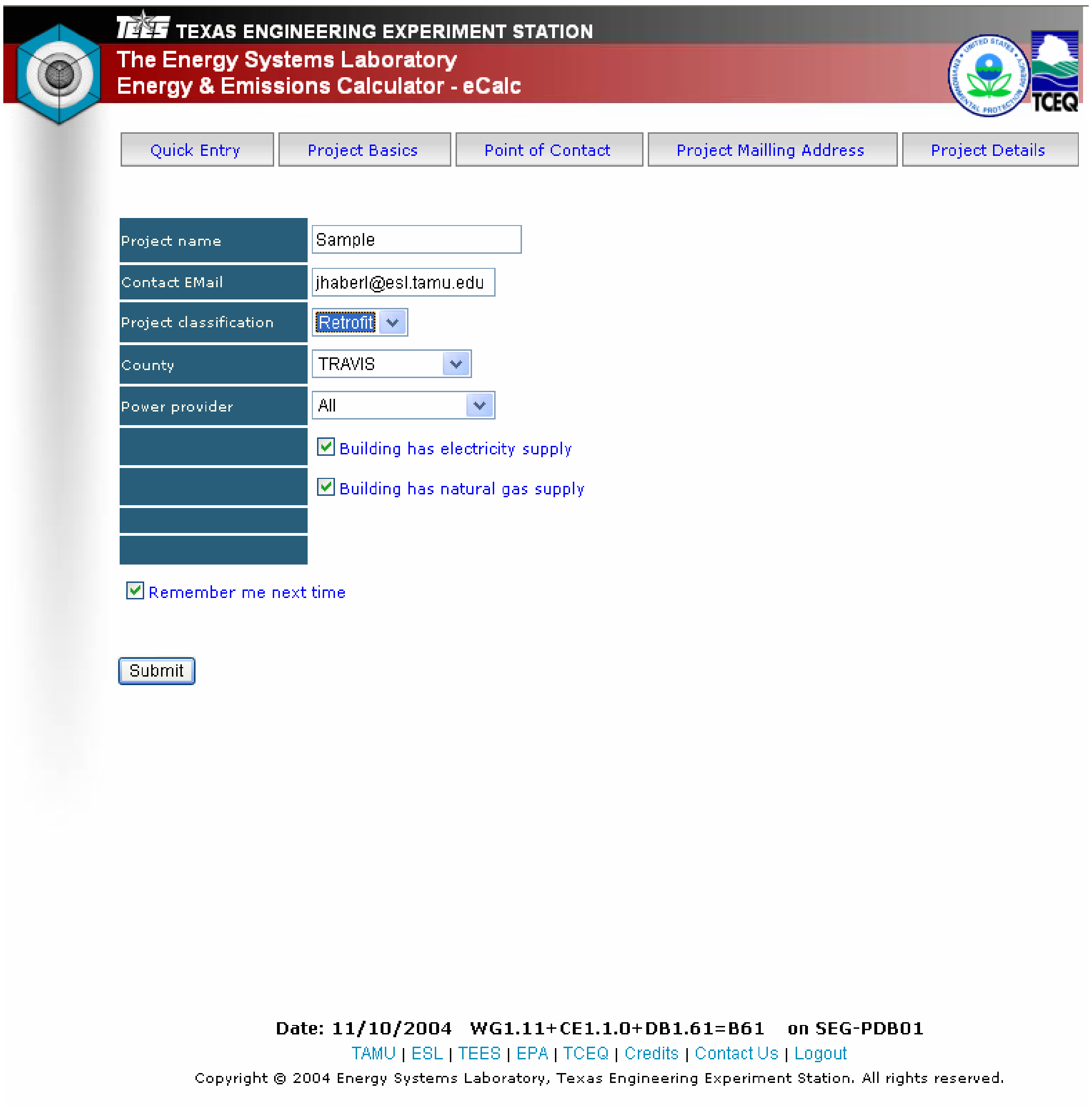


Figure 44: Municipal Water and Waste Water Retrofit Data Entry Screens (Project Input).

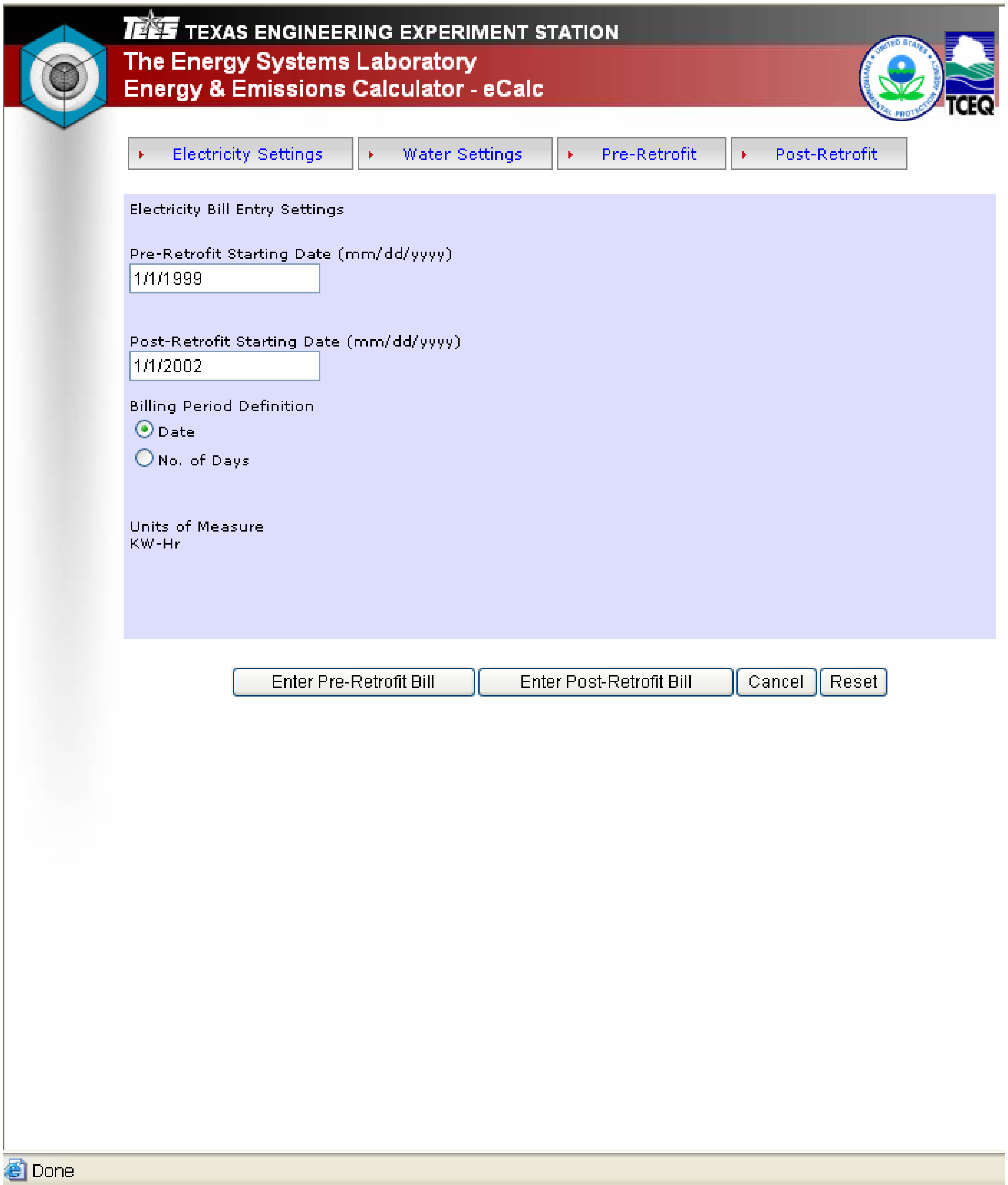


Figure 45: Municipal Water and Waste Water Retrofit Data Entry Screens (Project Pre and Post Dates).

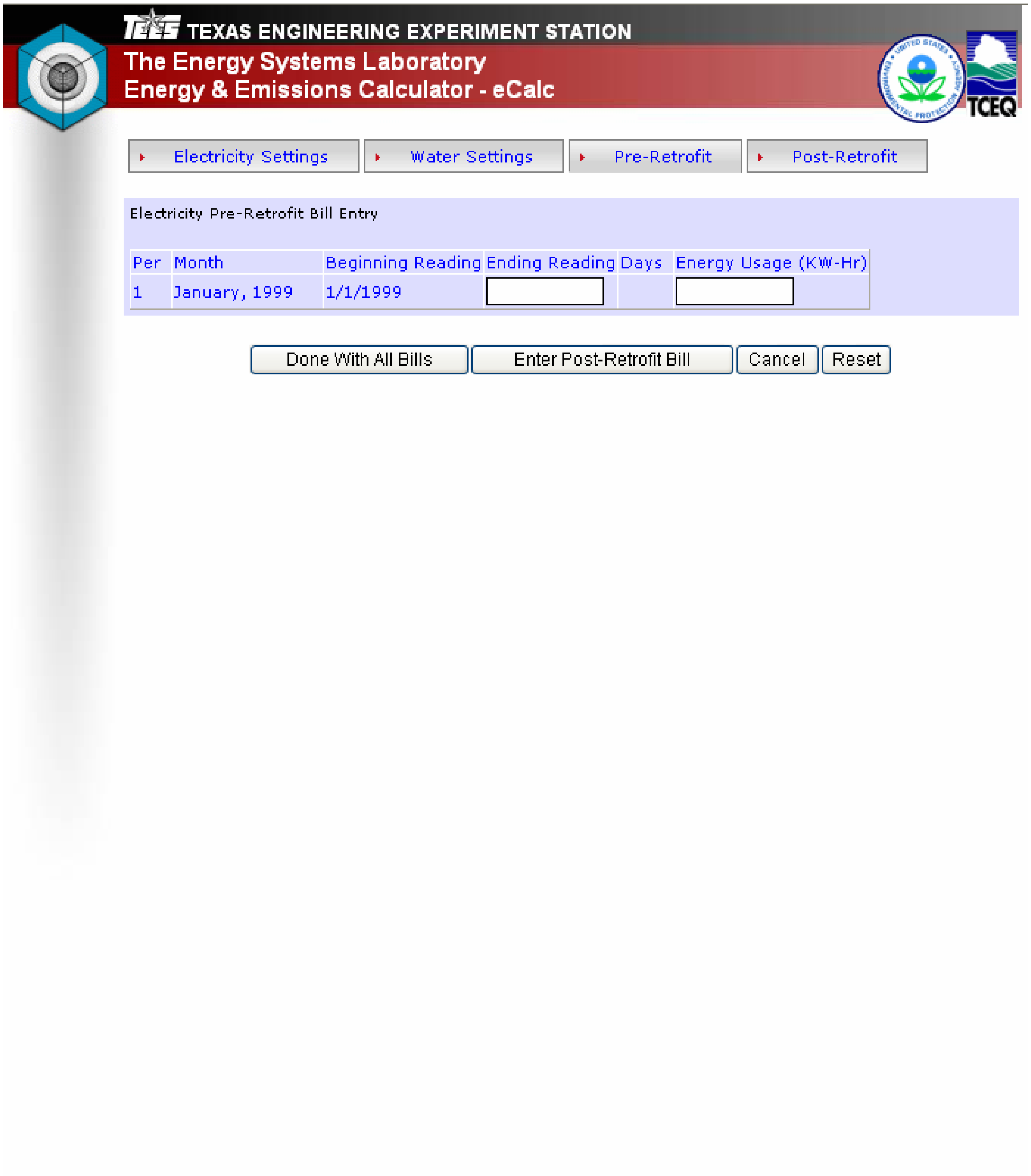


Figure 46: Municipal Water and Waste Water Retrofit Data Entry Screens (Pre and Post Utility Bill).

2.3.4 Municipal Water and Waste-water Analysis Description

When the user submits their municipal water and waste-water project for analysis, the emissions calculator performs a series of calculations, as indicated in Figure 47. For each analysis, the user is required to enter 12 pre-retrofit utility bills and 12 post-retrofit utility bills, as shown in Table 29. However, in difference to the previous analysis that used monthly utility billing data, the water and waste-water analysis requires that the user input monthly water used and electricity used by the pumps that supplied the water or handled the waste water.

To perform the appropriate weather normalization, ASHRAE's Inverse Model Toolkit (Kissock et al. 2002) is used in a two-step analysis. In the first step of the analysis, IMT is used to determine a statistical relationship between the pre-retrofit electricity used by the pumps and the water produced (i.e., municipal water supply system) or waste-water processed. This process is then repeated for the post-retrofit period. In the second step of the analsyis, IMT is used to develop change-point linear models for the pre-retrofit and post-retrofit periods using daily average NOAA weather data from the nearest weather location. As shown in Figure 47, IMT then produces pre-retrofit and post-retrofit coefficients (Table 20) that are used to determine the annual energy use in 1999 and the 1999 peak day energy use for the Ozone Episode Day (August 19, 1999), as shown in Figure 48. In the case of the water modeling, these savings are calculated for 1999 using the weather normalization for the post-retrofit period and the difference in the performance of the pumps (i.e., the coefficient for the kWh/Mgal) between the pre-retrofit and post-retrofit period.

In the next step of the analysis and in a similar fashion to the analysis shown for the residential simulation (Figure 10), the emissions calculator calculates the NOx, SOx, and CO_2 using the USEPA's eGRID database. These results are then reported by the emissions calculator in a format that is similar to that shown in Table 10 for residential and emailed to the user as HTML and XML files.

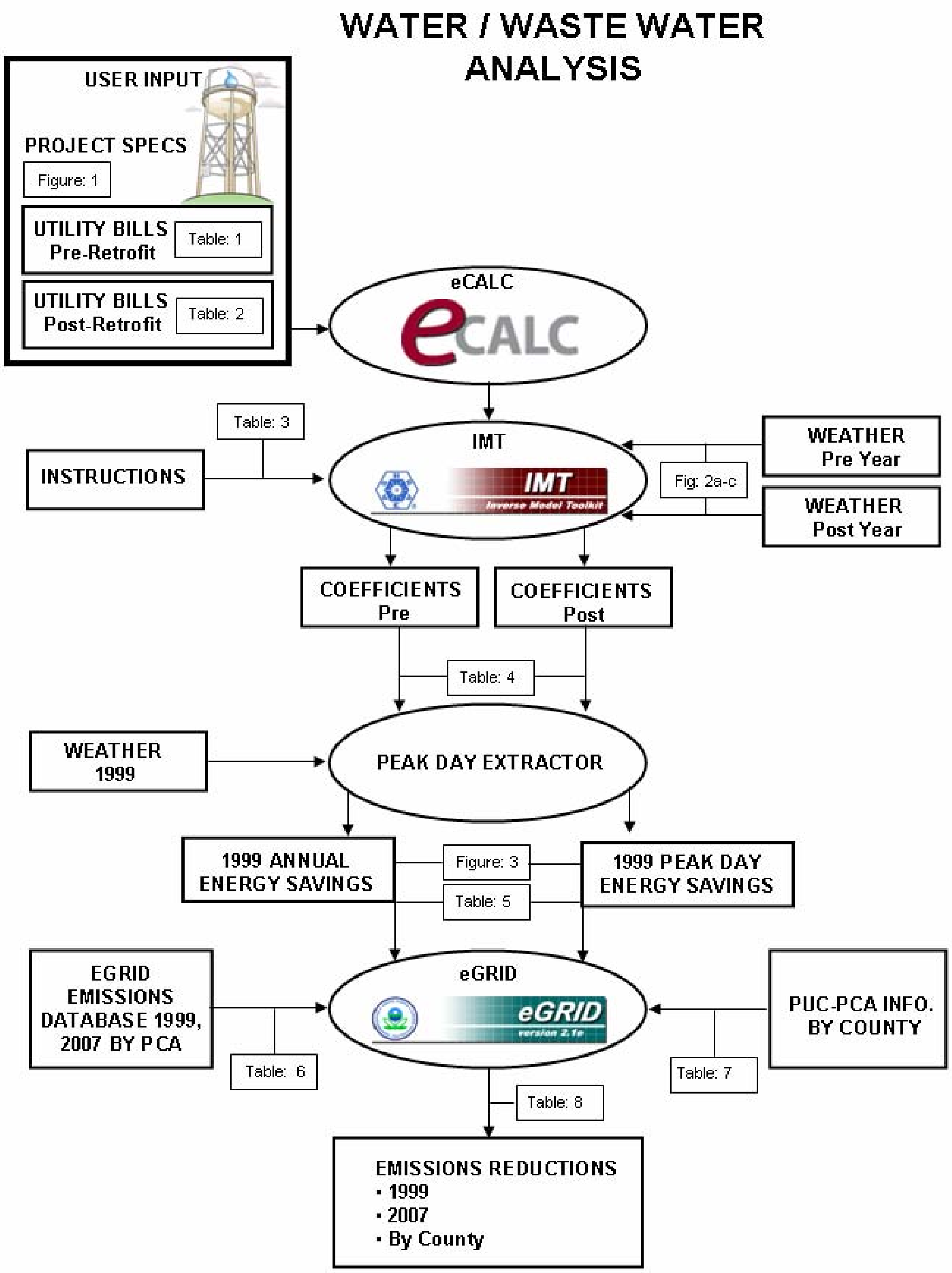


Figure 47: Municipal Water and Waste-water Analysis Flowchart.

Month	days	Water Consumption [gallon]	Electricity Consumption by pumping [kWh]
Jan-02	31	216,252,688	18,103
Feb-02	28	205,583,052	14,027
Mar-02	31	232,927,565	35,381
Apr-02	30	285,786,522	37,225
May-02	31	396,652,055	62,360
Jun-02	30	354,282,824	69,070
Jul-02	31	312,277,562	94,847
Aug-02	31	422,068,375	104,995
Sep-02	30	364,414,294	78,636
Oct-02	31	283,223,385	39,474
Nov-02	30	227,389,529	17,183
Dec-02	31	205,176,729	16,559

Table 1: Pre-Retrofit Sample Monthly Electricity Bills for Water Use and Pumping Electric Load

Month	days	Water Consumption [gallon]	Electricity Consumption by pumping [kWh]
Jan-03	31	205,440,054	15,388
Feb-03	28	195,303,900	11,923
Mar-03	31	221,281,186	30,074
Apr-03	30	271,497,196	31,641
May-03	31	376,819,452	53,006
Jun-03	30	336,568,683	58,710
Jul-03	31	296,663,684	80,620
Aug-03	31	400,964,956	89,246
Sep-03	30	346,193,579	66,841
Oct-03	31	269,062,216	33,553
Nov-03	30	216,020,052	14,606
Dec-03	31	194,917,892	14,075

Table 2:Post-Retrofit Sample Monthly Electricity Bills for Water Use and Pumping Electric Load

Table 29: Municipal Water and Waste-water Analysis Flowchart (Table 1: Pre-Retrofit Water and Electricity Bills and Table 2: Post-Retrofit Water and Electricity Bills).

```
Path and name of input data file = dataWWW.prn
Value of no-data flag = -99
Column number of group field = 4
Value of valid group field = 1
Residual file needed (1 yes, 0 no) = 1
Model type (1:Mean,2:2p,3:3pc,4:3ph,5:4p,6:5p,7:MVR,8:HDD,9:CDD) = 5
Column number of dependent Y variable = 3
Number of independent X variables (0 to 6)  = 1
Column number of independent variable X1 = 2
Column number of independent variable X2 = 0
Column number of independent variable X3 = 0
Column number of independent variable X4 = 0
Column number of independent variable X5 = 0
Column number of independent variable X6 = 0
```

Table3: Example of I.M.T Input File

Table 30: Municipal Water and Waste-water Analysis Flowchart (Table 3: Example IMT Input File).

```
********************************************
  ASHRAE INVERSE MODELING TOOLKIT (1.9)

********************************************
    Output file name = IMT.Out

********************************************
    Input data file name = DAILY2.dat
    Model type =            3P Cooling
    Grouping column No =    5
    Value for grouping =    1
    Residual mode =         1
    # of X(Indep.) Var =    1
    Y1 column number =      6
    X1 column number =   9
    X2 column number =   0 (unused)
    X3 column number =   0 (unused)
    X4 column number =   0 (unused)
    X5 column number =   0 (unused)
    X6 column number =   0 (unused)

********************************************
    Regression Results
           N =     12
          R2 =     0.835
       AdjR2 =     0.835
        RMSE =      1.0560
     CV-RMSE =    11.006%
           p =    -0.346
          DW =     2.682 (p>0)
          N1 =      3
          N2 =      9
   --------------------------------------
         Ycp =      6.9610 (      0.4799)
          LS =      0.0000 (      0.0000)
          RS =      0.1864 (      0.0262)
         Xcp =     55.0408 (      0.6926)
   --------------------------------------
```

Table4: Example of I.M.T Coefficients

Table 31: Municipal Water and Waste-water Analysis Flowchart (Table 4: Example IMT Coefficients).

Savings

75,521	kWh	Annual Energy Savings
	kWh	OSDsum
199	kWh	OSDavg
189.22	kWh	OSDpkChosen
	kWh	OSDpkActual

Table5: Examples of Energy Saving Outputs from Peak Day Extractor

Table 32: Municipal Water and Waste-water Analysis Flowchart (Table 4: Example Energy Savings from Peak Day Extractor).

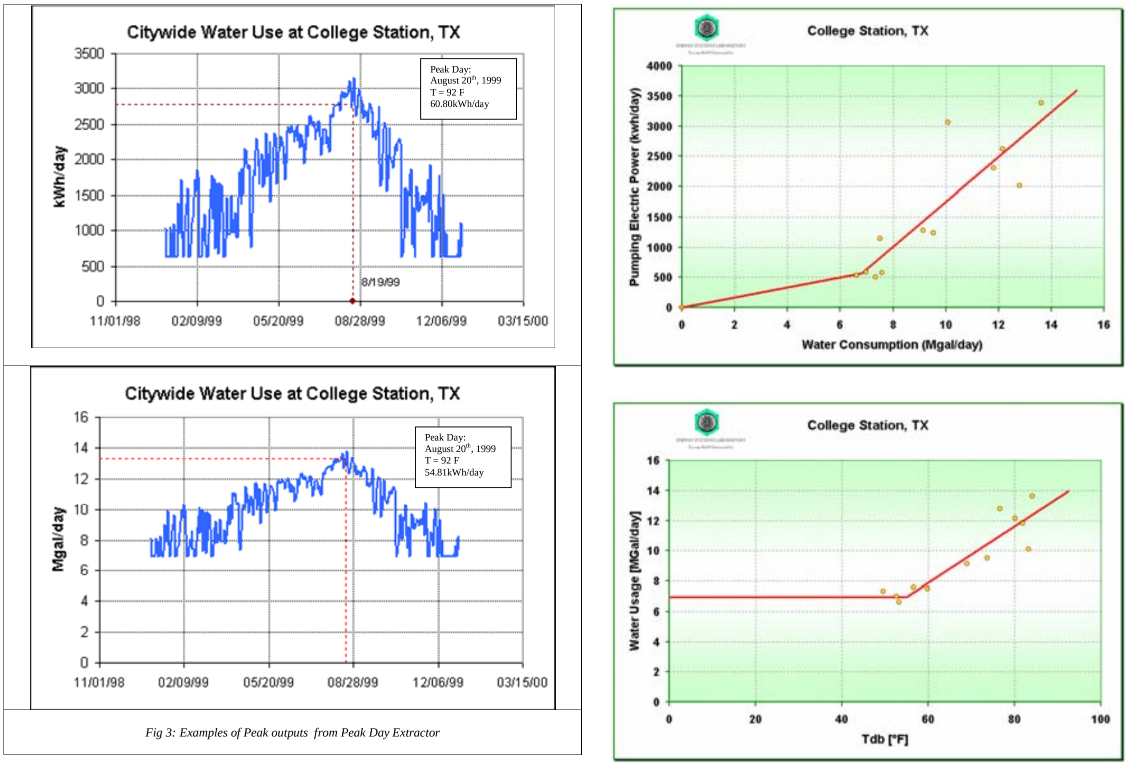


Figure 48: Municipal Water and Waste-water Analysis Flowchart (Figure 3: Examples of Peak Outputs from Peak Day Extractor).

2.3.5 Renewables

The emissions calculator contains several renewable energy systems, including solar thermal, solar photovoltaic, and wind energy systems. The solar thermal and solar photovoltaic analyses use the F-CHART software, which was developed by the University of Wisconsin for the U.S. Department of Energy Klein and Beckman (1983). The wind energy analysis uses a two-step monthly analysis procedure similar to that used in the water and waste-water analysis.

2.3.5.1 Solar PV Input Screens

The user input screens for solar photovoltaic projects begin with the project input screen shown in Figure 49. In this input screen the user is asked for their project name, their email address, and what type of PV system this is (e.g., high efficiency, or average efficiency). When the user submits this type of project to the emissions calculator, they are directed to the next screen for photovoltaic projects shown in Figure 50. This input screen asks for specific information about the array of solar photovoltaic collectors, including the area of the array, the slope of the array as measured from the horizontal, and whether or not the collector array is facing south (i.e., array azimuth). When the user completes the screen shown in Figure 50, the project is submitted for analysis.

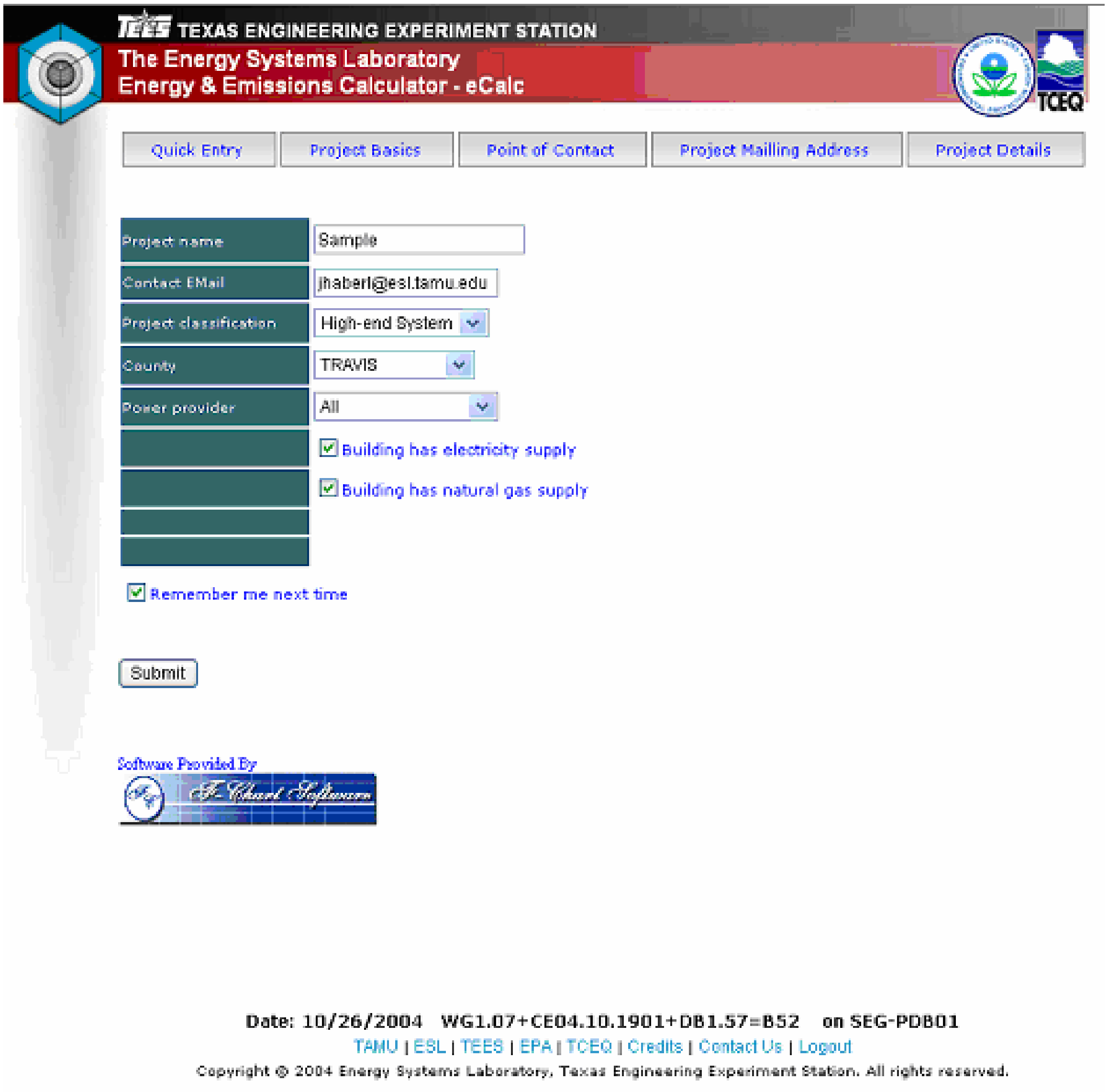


Figure 49: Solar PV Input Screens (Project Info).

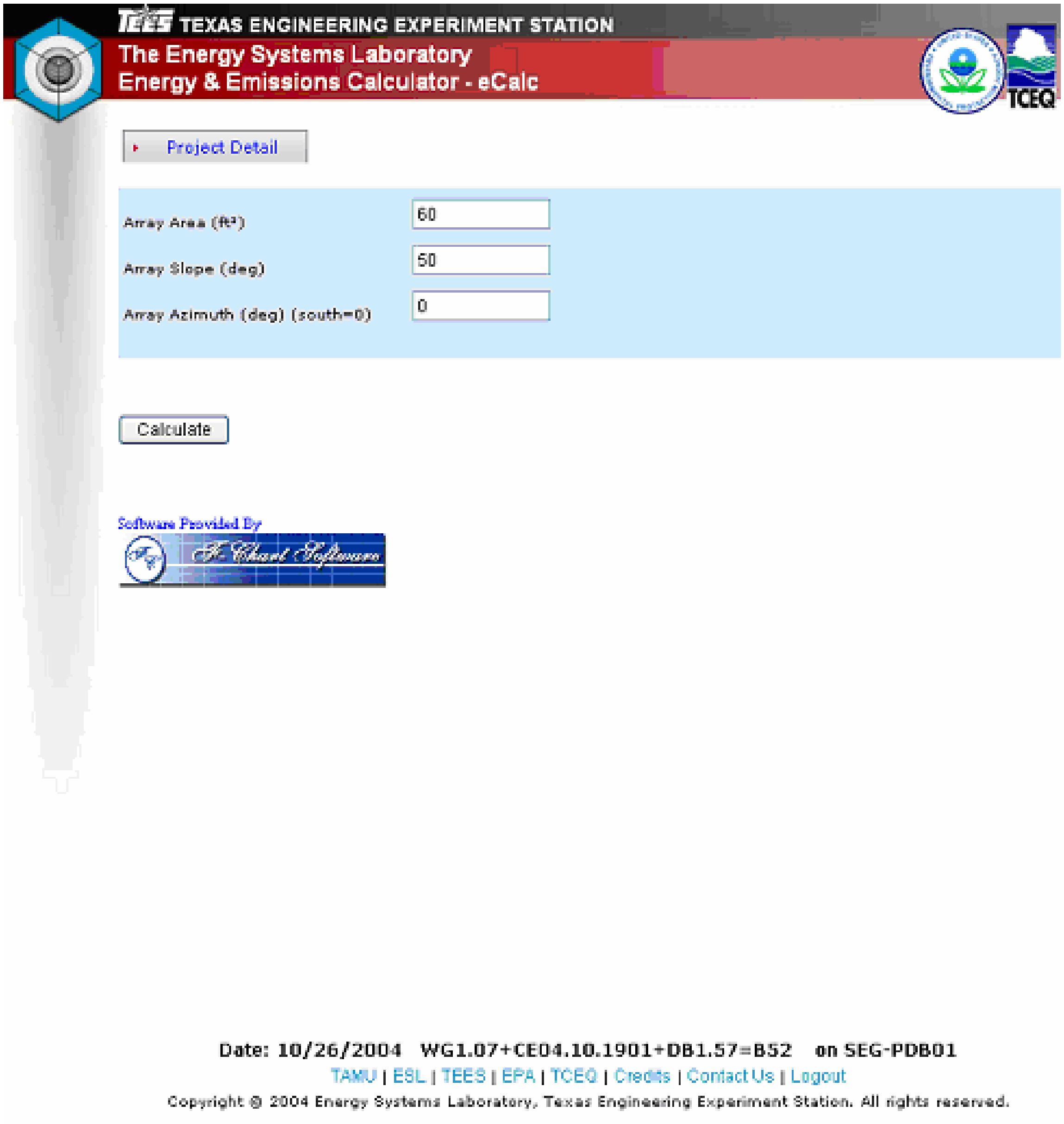


Figure 50: Solar PV Input Screens (Project detail).

2.3.5.2 Solar PV Analysis Description

When the user submits their solar photovoltaic project for analysis, the emissions calculator takes the information provided by the user and tables of additional information[20] (Table 33 and Table 34), and calls the PV F-CHART program. The PV F-CHART program then calculates the monthly electricity produced by the system specified by the user at the latitude associated with the county selected using PV F-CHART's weather data from the nearest location (Table 35). In the next step, the emissions calculator takes the 12 months of predicted electricity production from the solar collector array and creates a weather-normalized electricity production that can then be applied to the 1999 weather data. This is accomplished with the ASHRAE IMT (Table 36 and Table 37). Figure 52, Figure 53, and Figure 54 show examples of the 12 month renewable energy production and peak-day performance.

In the next step of the analysis and in a similar fashion to the analysis shown for the residential simulation (Figure 10), the emissions calculator calculates the NOx, SOx, and CO_2 using the USEPA's eGRID database. These results are then reported by the emissions calculator in a format that is similar to that shown in Table 10 for residential and emailed to the user as HTML and XML files.

[20] Data in the emissions calculator is from the following photovoltaic manufacturers: Low efficiency, Model: Solarex SX-10, Southwest Photovoltaic Systems, Inc., 212 E. Main, Tomball, TX 77373. High efficiency, Model: Shell SP75, Shell Solar, 4650 Adohr Lane, Camarilo, CA, 93012.

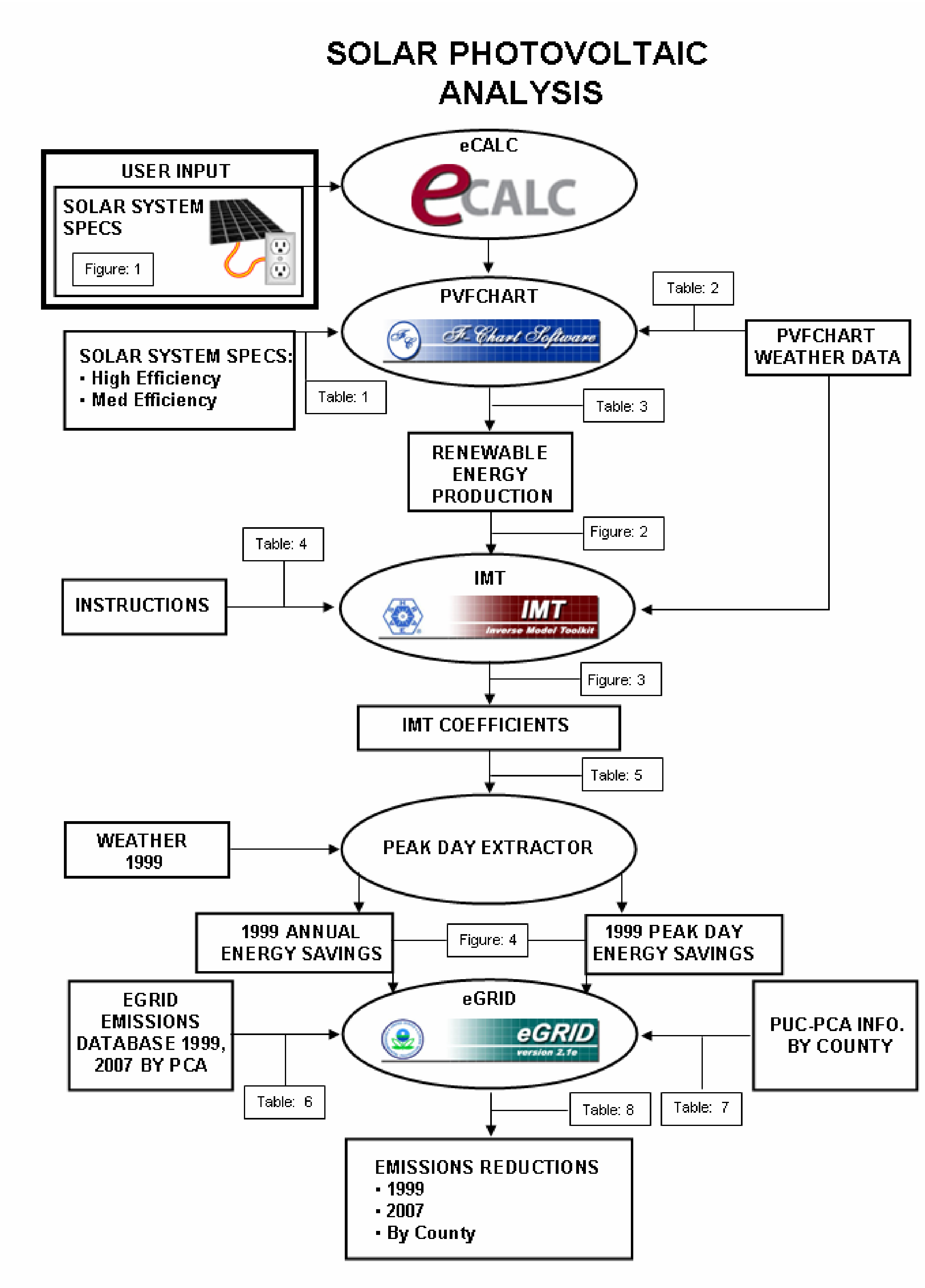


Figure 51: Solar Photovoltaic Analysis Flowchart

```
                        ** Stand Alone System **

1  City number for AUSTIN          TX................  18
2  Output: 1 for summary, 2 for detailed (Neg: graph)  1
3  Cell temperature at NOCT conditions...............  113   F
4  Array reference efficiency........................  .1184
5  Array reference temperature.......................  77    F
6  Max. power eff. temperature coeff. (times 1000)...  2.5   1/F
7  Eff. of maximum power point tracking electronics..  .9
8  Efficiency of power conditioning electronics......  .88
9  Percent standard deviation of the load............  0     %
10 Array area........................................  60    ft^2
11 Array slope.......................................  50    deg
12 Array azimuth (south=0)...........................  0     deg

                        *** Economics ***
1   Econonomic analysis detail (0 to 4)..............  0
```

Table 1:Photovoltaic systems specifications

Table 33: Solar Photovoltaic Analysis Flowchart (Table 1: Photovoltaic system specs.).

AUSTIN TX LAT= 30

	SOLAR BTU/FT2	TEMP F	T SKY F	MAINS F	REFLEC	HUMID LB/LB
JAN	945	48.2	22.0	66.4	0.2	0.0057
FEB	1199	52.3	24.9	66.6	0.2	0.0057
MAR	1498	60.6	40.6	67.0	0.2	0.0094
APR	1717	68.5	53.6	67.4	0.2	0.0124
MAY	1869	74.3	60.6	67.7	0.2	0.0132
JUN	2092	80.2	68.2	68.0	0.2	0.0159
JUL	2152	83.3	71.3	68.1	0.2	0.0167
AUG	2005	83.5	70.6	68.2	0.2	0.0159
SEP	1663	78.1	65.6	67.9	0.2	0.0151
OCT	1383	69.3	51.6	67.4	0.2	0.0117
NOV	1049	59.4	37.3	67.0	0.2	0.0082
DEC	883	51.1	25.0	66.5	0.2	0.0057

Table 2: PVFchart weather data

Table 34: Solar Photovoltaic Analysis Flowchart (Table 2: PV F-Chart weather data).

Summary

	Solar kWh	Load kWh	F %	Buy kWh	XS kWh
Jan	722.1	0.0	100.0	0.0	64.0
Feb	717.8	0.0	100.0	0.0	62.6
Mar	850.8	0.0	100.0	0.0	71.6
Apr	804.3	0.0	100.0	0.0	65.9
May	789.5	0.0	100.0	0.0	63.4
Jun	801.7	0.0	100.0	0.0	62.9
Jul	872.1	0.0	100.0	0.0	67.9
Aug	915.6	0.0	100.0	0.0	71.7
Sep	866.0	0.0	100.0	0.0	69.3
Oct	903.5	0.0	100.0	0.0	74.5
Nov	756.5	0.0	100.0	0.0	65.0
Dec	702.0	0.0	100.0	0.0	61.9
Yr	9701.9	0.0	100.0	0.0	800.8

Table 3:PVFchart output data

Table 35: Solar Photovoltaic Analysis Flowchart (Table 3: PV F-Chart output data).

```
Path and name of input data file = dflt_fchart.prn
Value of no-data flag = -99
Column number of group field = 0
Value of valid group field = 1
Residual file needed (1 yes, 0 no) = 1
Model type (1:Mean,2:2p,3:3pc,4:3ph,5:4p,6:5p,7:MVR,8:HDD,9:CDD) = 4
Column number of dependent Y variable = 7
Number of independent X variables (0 to 6)  = 1
Column number of independent variable X1 = 1
Column number of independent variable X2 = 0
Column number of independent variable X3 = 0
Column number of independent variable X4 = 0
Column number of independent variable X5 = 0
Column number of independent variable X6 = 0
```

Table 4:Input into Inverse Modeling Toolkit

Table 36: Solar Photovoltaic Analysis Flowchart (Table 4: Input into Inverse Modeling Toolkit).

```
********************************************
 ASHRAE INVERSE MODELING TOOLKIT (1.9)
 ********************************************
   Output file name = IMT.Out
 ********************************************
   Input data file name =  dflt_fchart.prn
   Model type =           3P Heating
   Grouping column No =    0
   Value for grouping =    1
   Residual mode =         1
   # of X(Indep.) Var =    1
   Y1 column number =      6
   X1 column number =   1
   X2 column number =   0 (unused)
   X3 column number =   0 (unused)
   X4 column number =   0 (unused)
   X5 column number =   0 (unused)
   X6 column number =   0 (unused)
 ********************************************
   Regression Results
  -------------------------------------
         N =     12
  -------------------------------------
        R2 =     0.251
  -------------------------------------
     AdjR2 =     0.251
  -------------------------------------
      RMSE =      0.1143
  -------------------------------------
   CV-RMSE =     5.208%
  -------------------------------------
         p =     0.436
  -------------------------------------
        DW =     1.015 (p>0)
  -------------------------------------
        N1 =      3
  -------------------------------------
        N2 =      9
  -------------------------------------
       Ycp =      2.2254 (      0.0371)
  -------------------------------------
        LS =      0.0311 (      0.0170)
  -------------------------------------
        RS =      0.0000 (      0.0000)
  -------------------------------------
       Xcp =     54.5540 (      0.7060)
  -------------------------------------
  --------------------------------
```

Table 5:Inverse Modeling Toolkit output

Table 37: Solar Photovoltaic Analysis Flowchart (Table 5: IMT Output).

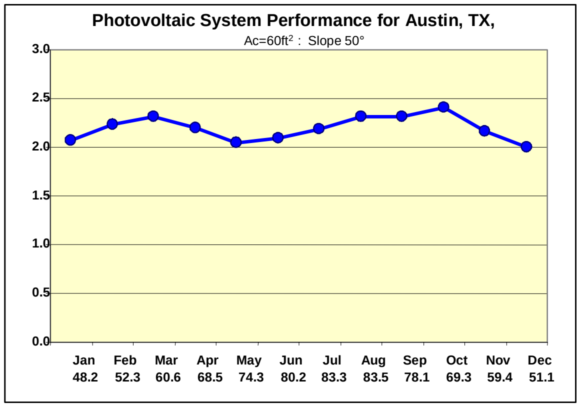


Figure 2: Renewable Energy Production

Figure 52: Solar Photovoltaic Analysis Flowchart (Figure 2: Renewable Energy Production).

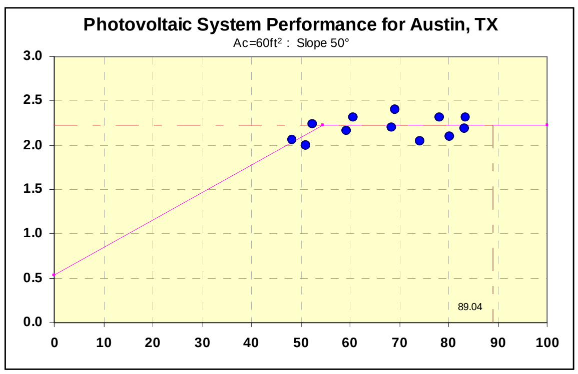


Figure 3: Output from Inverse Modeling Toolkit

Figure 53: Solar Photovoltaic Analysis Flowchart (Figure 3: Output from IMT).

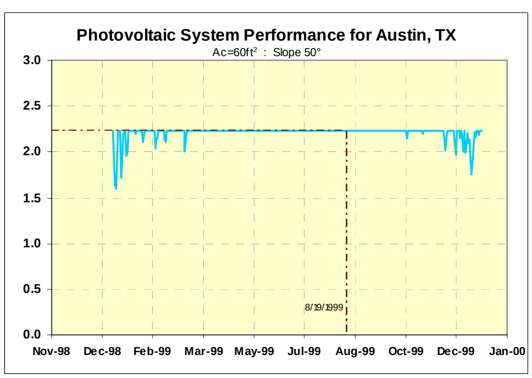


Figure 4: Annual and Peak Day Energy Savings

Figure 54: Solar Photovoltaic Analysis Flowchart (Figure 4: Annual and Peak Day Energy Savings).

2.3.5.3 Solar Thermal

The emissions calculator offers renewable analysis for two types of solar thermal systems: a system for heating domestic hot water (DHW), and a system for heating swimming pools. Both systems are analyzed with the F-CHART software.

2.3.5.3.1 Solar Thermal - Pool Heating System Input Screens

The user input screens for solar thermal pool heating projects begin with the project input screen shown in Figure 55. In this input screen, the user is asked for their project name, their email address, and what type of solar system this is (i.e., DHW or pool heating). When the user submits the project information to the emissions calculator, they are directed to the next screen for solar thermal projects shown in Figure 56. This input screen asks for specific information about the array of solar thermal collectors, including the area of the array, the slope of the array as measured from the horizontal, and whether or not the collector array is facing south (i.e., array azimuth). When the user completes the screen shown in Figure 56, they have the option of revising additional default information about pools, as shown in Figure 57, which includes information about the surface area of the pool, depth of the pool, pool temperature, type of cover (if any), hours per day the pool is covered, location of the pool, and the percent of the pool that is shaded. When the user completes the data entry requested Figure 57 and submits the project for calculation, the emissions calculator then calculates the thermal energy produced by the solar thermal pool heating system and emails the output to the address the user entered in the project information screen.

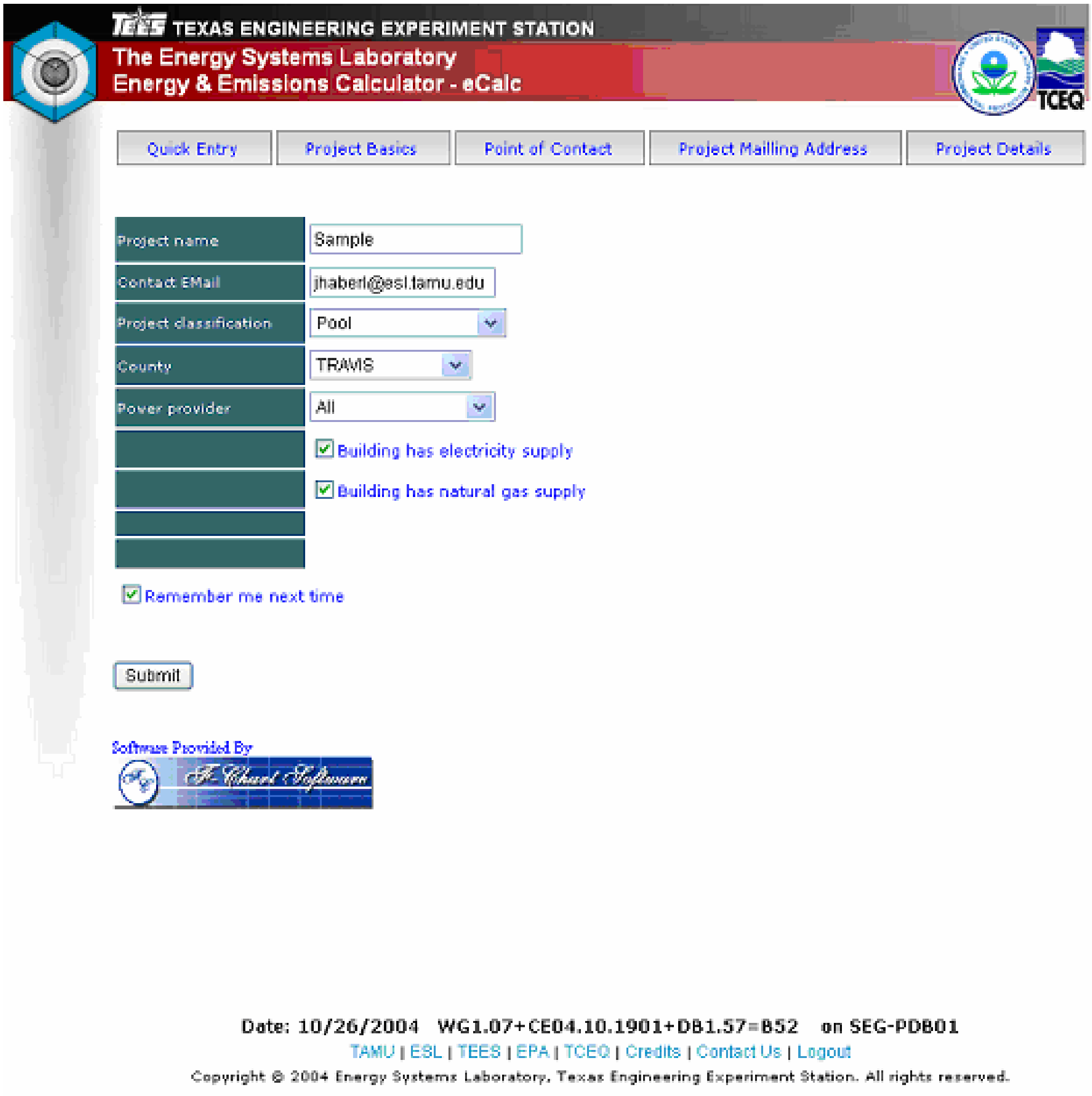


Figure 55: Solar Thermal - Pool Heating System Input Screens (Project Info).

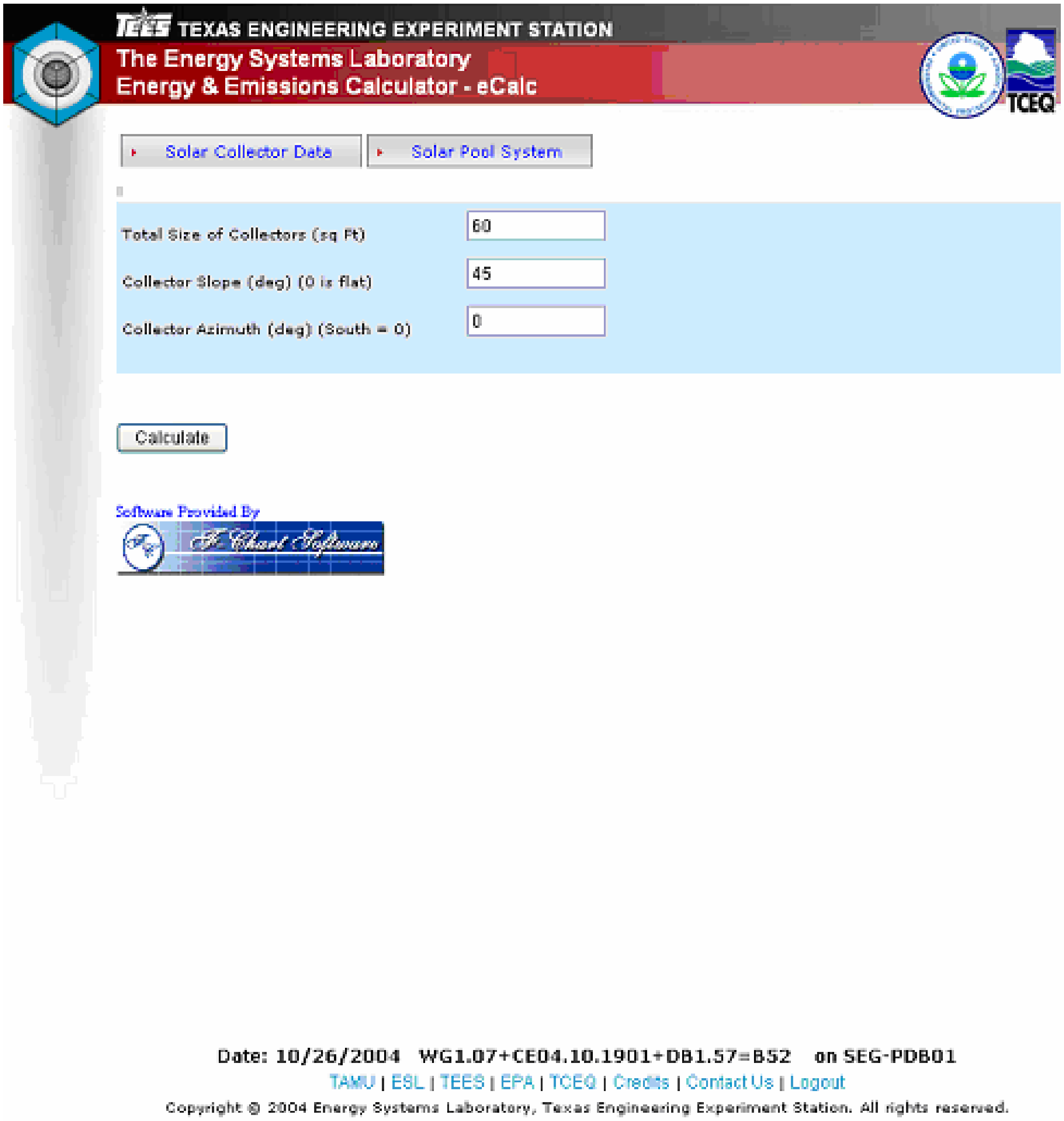


Figure 56: Solar Thermal - Pool Heating System Input Screens (Solar Collector Input).

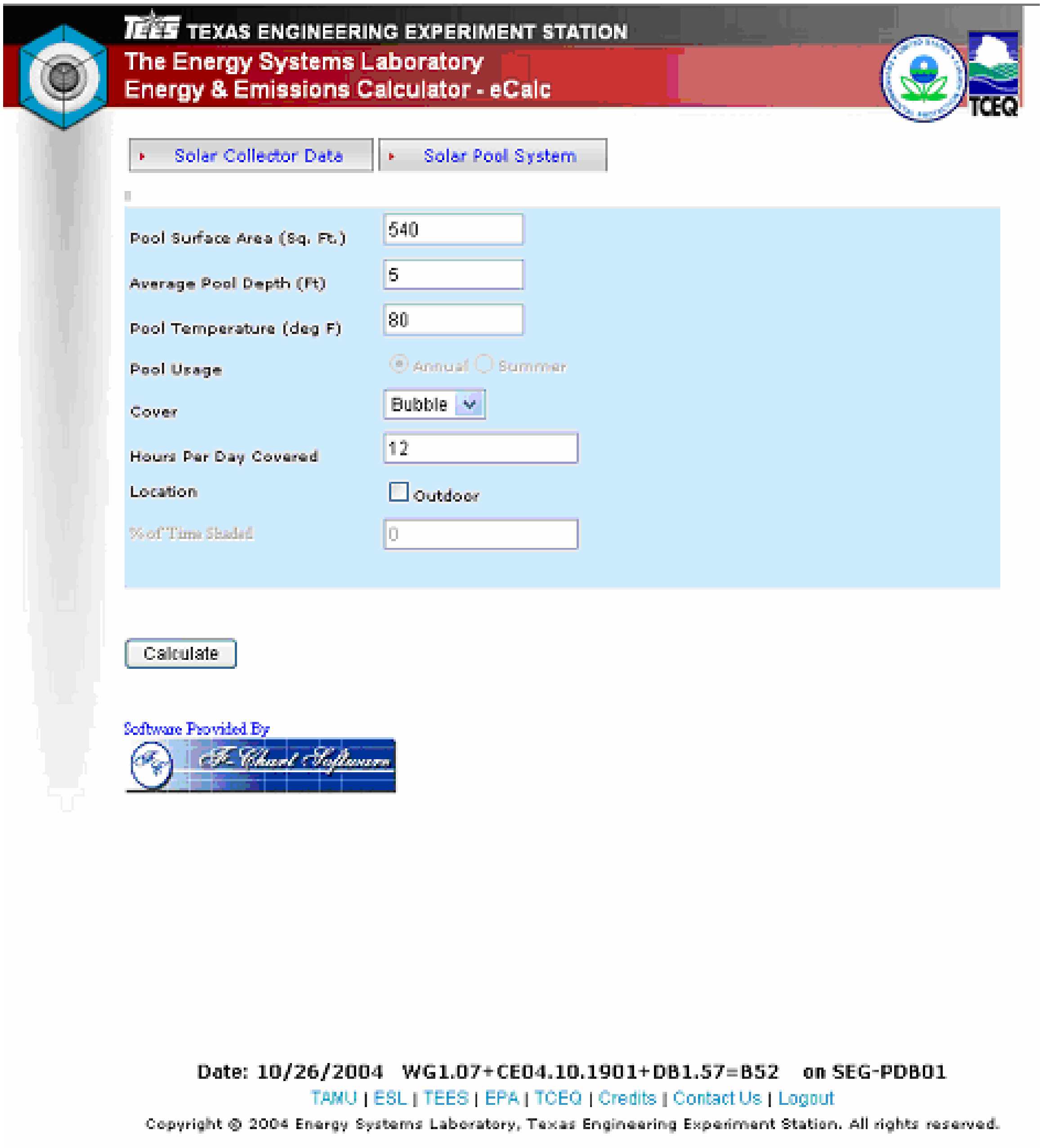


Figure 57: Solar Thermal - Pool Heating System Input Screens (Pool System Info).

2.3.5.3.2 Solar Thermal - DHW Heating System Input Screens

The user input screens for solar thermal domestic water heating (DHW) projects begin with the project input screen shown in Figure 58. In this input screen, the user is asked for their project name, their email address, and what type of solar system this is (i.e., DHW or pool heating). When the user submits the project information to the emissions calculator, they are directed to the next screen for solar thermal projects shown in Figure 59. This input screen asks for specific information about the array of solar thermal collectors, including the area of the array, the slope of the array as measured from the horizontal, and whether or not the collector array is facing south (i.e., array azimuth). When the user completes the screen shown in Figure 59, they have the option of revising additional default information about the DHW system, as shown in Figure 60, which includes information about the daily hot water usage and DHW storage tank size. When the user completes the data entry requested Figure 60 and submits the project for calculation, the emissions calculator then calculates the thermal energy produced by the solar thermal DHW system and emails the output to the address the user entered in the project information screen.

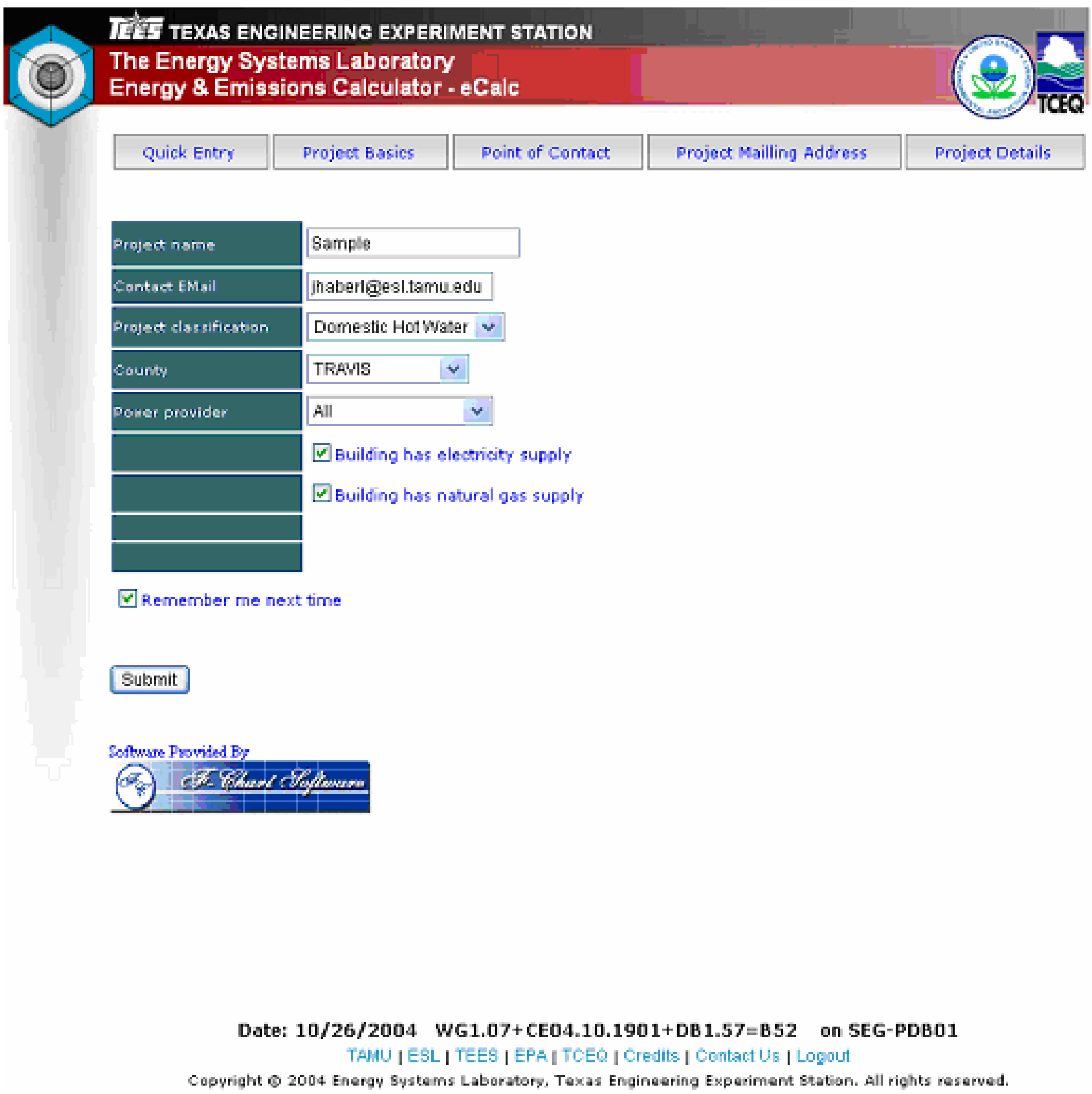


Figure 58: Solar Thermal - DHW Heating System Input Screens (Project Info).

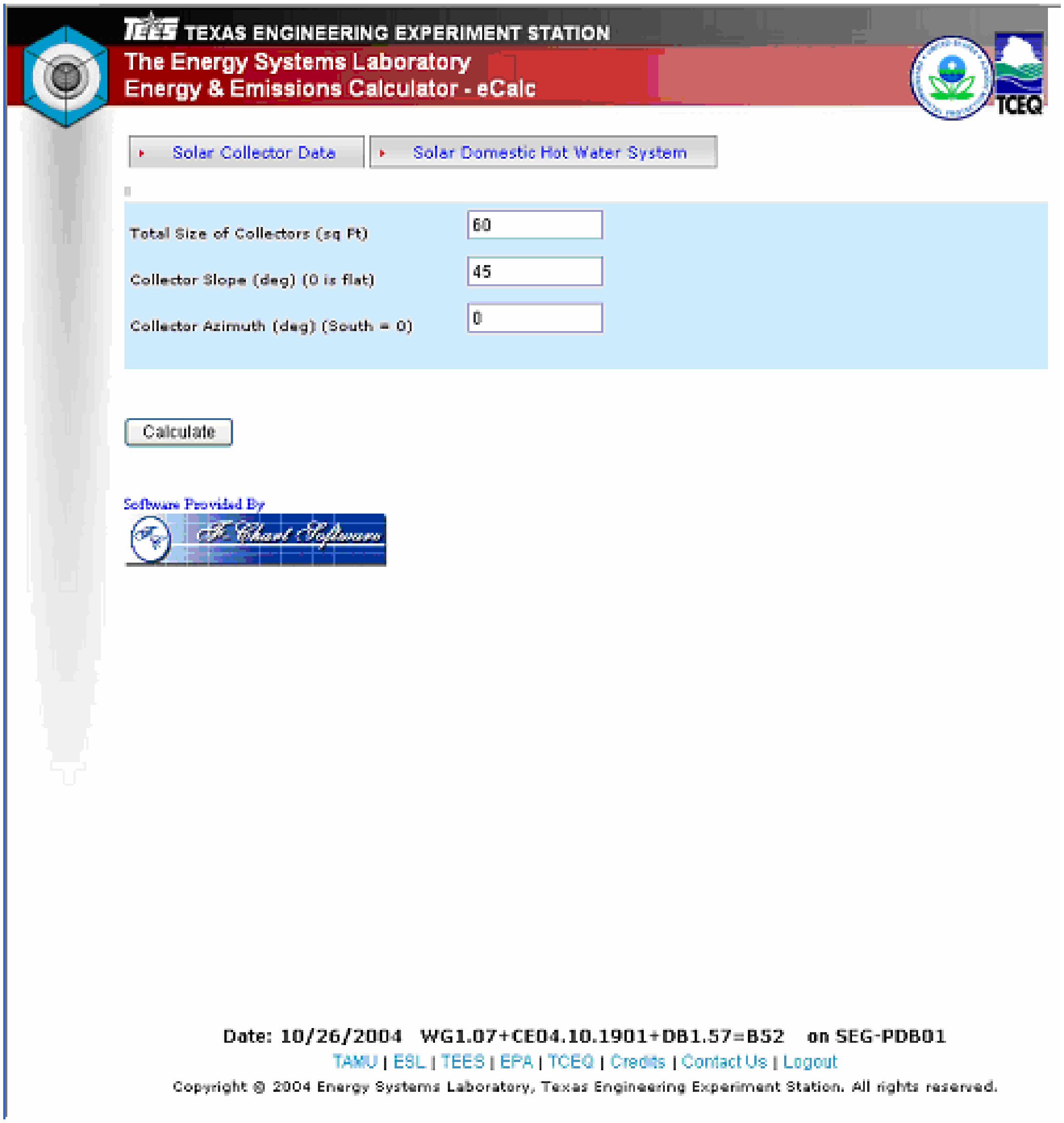


Figure 59: Solar Thermal - DHW Heating System Input Screens (Solar Collector Info).

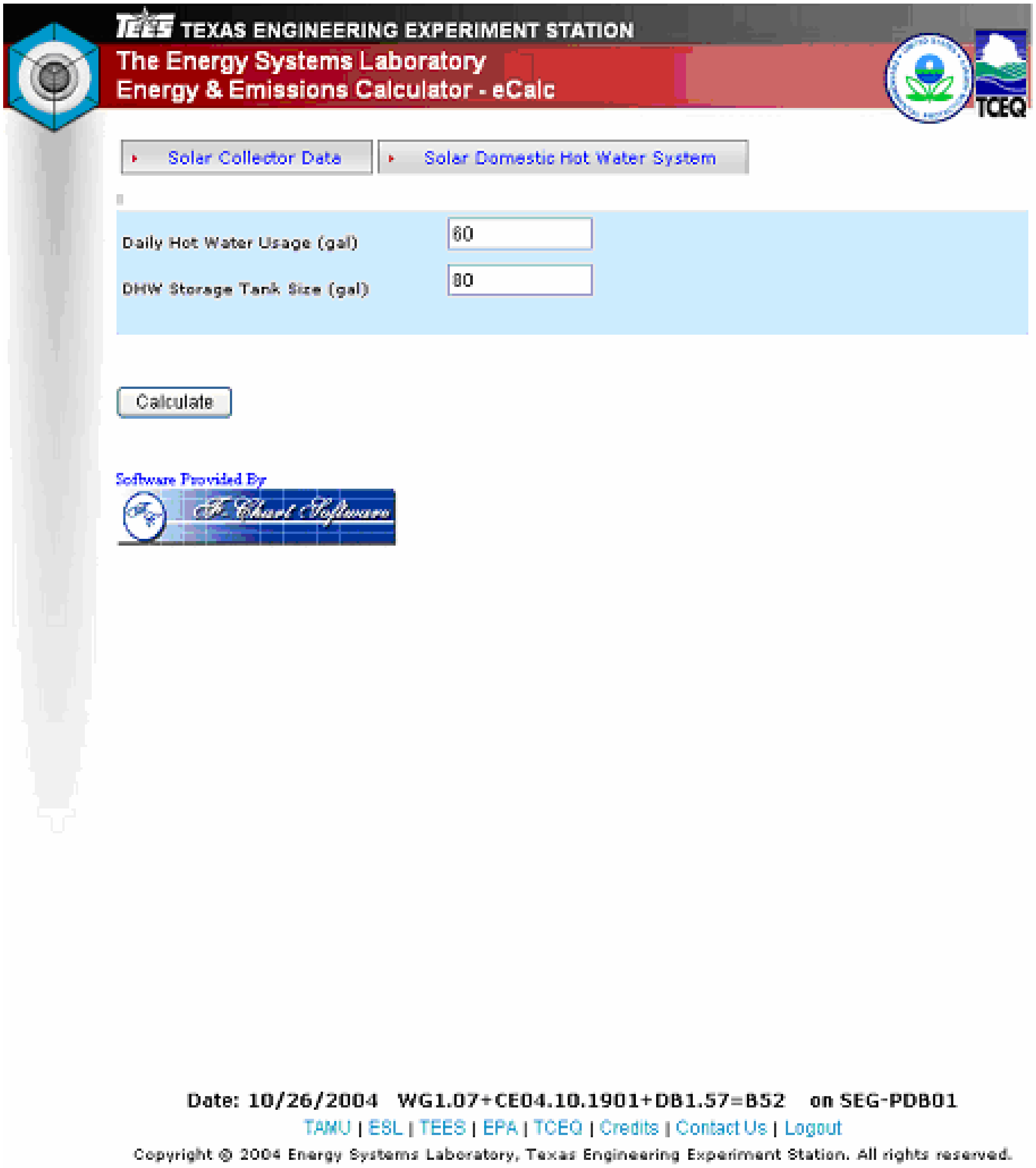


Figure 60: Solar Thermal - DHW Heating System Input Screens (Domestic Water Heating Info).

2.3.5.3.3 Solar Thermal Analysis Description (DHW and Pool)

When the user submits their solar thermal project for analysis, the emissions calculator takes the information provided by the user and tables of additional information[21] (Table 38 and Table 39), and calls the F-CHART program. The F-CHART program then calculates the monthly thermal energy produced by the system specified by the user at the latitude associated with the county selected using F-CHART's weather data from the nearest location (Table 39). In the next step, the emissions calculator takes the 12 months of predicted thermal energy production from the solar collector array (Table 40) and creates a weather-normalized thermal energy production that can then be applied to the 1999 weather data. This is accomplished with the ASHRAE IMT (Table 41 and Table 42). Figure 62, Figure 63, and Figure 64 show examples of the 12 month renewable energy production and peak-day performance.

In the next step of the analysis, in a similar fashion to the analysis shown for the residential simulation (Figure 10), the emissions calculator calculates the NOx, SOx, and CO_2 using the USEPA's eGRID database. These results are then reported by the emissions calculator in a format that is similar to that shown in Table 10 for residential and emailed to the user as HTML and XML files.

[21] Data in the emissions calculator is from the following solar collector manufacturers: Pool System: Model: SI 1500 Solar Pool Heating Collector, Solar Systems Installations, P.O. Box 736, Coppell, TX 75019-0736. Domestic Hot Water System: Model: SI 1500 Solar Pool Heating Collector, Alternate Energy Technologies, LLC, 1057 N. Ellis Road Unit 4, Jacksonville, FL 32254.

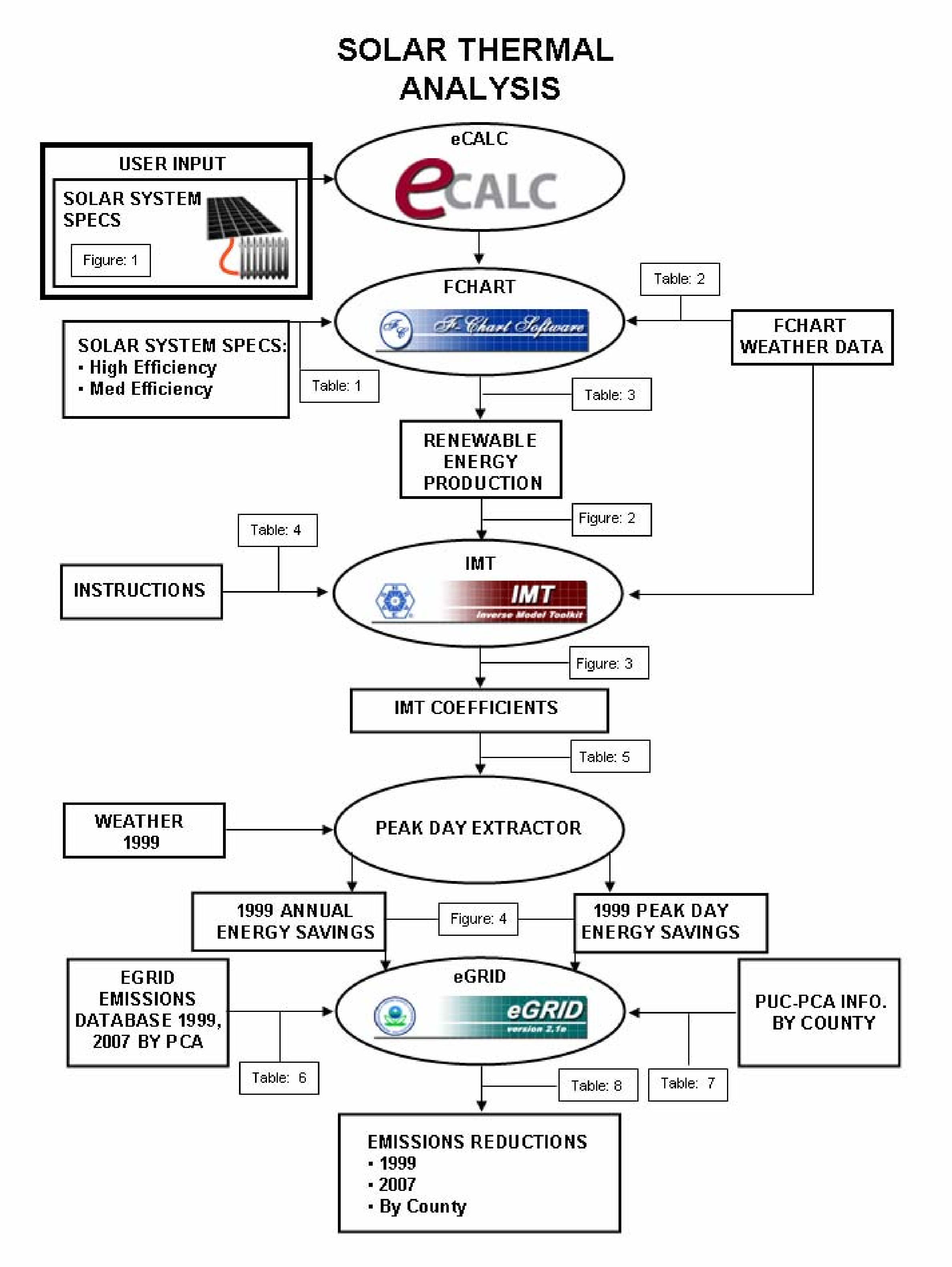


Figure 61: Solar Thermal Analysis Flowchart.

*** POOL HEATING SYSTEM *** 1 City call number.............. 14 2 Pool surface area............. 540 FT2 3 Pool temperature.............. 80 F 4 First month of use (1-12)..... 1 5 Last month of use (1-12)...... 12 6 Cover (0=None,1=Film,2=Bubble) 2 7 Hours per day covered......... 12 HR/DAY 8 Average pool depth............ 5 FT 9 Location (1=Indoor, 2=Outdoor) 1 10 % of time shaded.....(Outdoor) 0 % 11 Avgerage windspeed...(Outdoor) 5 MILES/HR 12 Pool room rel humidity(Indoor) 50 % 13 Pool room temperature (Indoor) 75 F 14 Fuel (1=EL,2=NG,3=OIL,4=OTHER) 2 15 Efficiency of fuel usage...... 70 % 16 Pipe heat loss (1=Y,2=N)...... 2 17 Inlet pipe UA............... 5 BTU/HR-F 18 Outlet pipe UA.............. 5 BTU/HR-F ** FLAT PLATE COLLECTOR ** 1 Number of collector panels.... 60 2 Collector panel area.......... 1 FT2 3 FR*UL (test slope)............ 2.9 BTU/HR-FT2-F 4 FR*TAU*ALPHA (test intercept). .84 5 Collector slope............... 45 DEG 6 Collector azimuth (South=0)... 0 DEG 7 Inicdence angle mod TYPE(8-10) 8 8 Number of glazings.......... 0 9 Inc angle modifier constant. 0 10 Inc angle modifier value(s). 1 .999 .998 .995 .981 .953 .882 .7 .35 0 11 Collector flowrate/area....... 11 LB/HR-FT2 12 Collector fluid specific heat. 1 BTU/LB-F 13 Modify test values (1=Y,2=N).. 2 14 Test collector flowrate/area 11 LB/HR-FT2 15 Test fluid specific heat.... 1 BTU/LB-F Table 1: Solar Collector Specifications	*** WATER STORAGE SYSTEM *** 1 City call number.............. 14 2 Water storage volume.......... 1000 GALLONS 3 Building UA (0 for DHW only).. 0 BTU/HR-F 4 Fuel (1=EL,2=NG,3=OIL,4=OTHER) 1 5 Efficiency of fuel usage...... 100 % 6 Domestic hot water (1=Y,2=N).. 1 7 Daily hot water usage....... 60 GALLONS 8 Water set temperature....... 140 F 9 Environment temperature..... 68 F 10 DHW storage tank size....... 80 GALLONS 11 UA of aux storage tank...... 7.6 BTU/HR-F 12 Pipe heat loss (1=Y,2=N)...... 2 13 Inlet pipe UA............... 5 BTU/HR-F 14 Outlet pipe UA.............. 5 BTU/HR-F 15 Relative load HX size......... 1 16 Collector-storage HX (1=Y,2=N) 2 17 Tank side flowrate/area..... 11 LB/HR-FT2 18 Heat exchanger effectiveness .5 ** FLAT PLATE COLLECTOR ** 1 Number of collector panels.... 60 2 Collector panel area.......... 1 FT2 3 FR*UL (test slope)............ 1.07 BTU/HR-FT2-F 4 FR*TAU*ALPHA (test intercept). .78 5 Collector slope............... 45 DEG 6 Collector azimuth (South=0)... 0 DEG 7 Inicdence angle mod TYPE(8-10) 8 8 Number of glazings.......... 1 9 Inc angle modifier constant. 0 10 Inc angle modifier value(s). 1 .999 .998 .995 .981 .953 .882 .7 .35 0 11 Collector flowrate/area....... 11 LB/HR-FT2 12 Collector fluid specific heat. 1 BTU/LB-F 13 Modify test values (1=Y,2=N).. 2 14 Test collector flowrate/area 11 LB/HR-FT2 15 Test fluid specific heat.... 1 BTU/LB-F

Table 38: Solar Thermal Analysis Flowchart (Table 1: Solar collector specs.).

AUSTIN		TX		LAT= 30		
	SOLAR	TEMP	T SKY	MAINS	REFLEC	HUMID
	BTU/FT2	F	F	F		LB/LB
JAN	945	48.2	22.0	66.4	0.2	0.0057
FEB	1199	52.3	24.9	66.6	0.2	0.0057
MAR	1498	60.6	40.6	67.0	0.2	0.0094
APR	1717	68.5	53.6	67.4	0.2	0.0124
MAY	1869	74.3	60.6	67.7	0.2	0.0132
JUN	2092	80.2	68.2	68.0	0.2	0.0159
JUL	2152	83.3	71.3	68.1	0.2	0.0167
AUG	2005	83.5	70.6	68.2	0.2	0.0159
SEP	1663	78.1	65.6	67.9	0.2	0.0151
OCT	1383	69.3	51.6	67.4	0.2	0.0117
NOV	1049	59.4	37.3	67.0	0.2	0.0082
DEC	883	51.1	25.0	66.5	0.2	0.0057

Table 2: Fchart weather data

Table 39: Solar Thermal Analysis Flowchart (Table 2: F-Chart weather data).

*** POOL HEATING SYSTEM ***
** FLAT PLATE COLLECTOR **

			QCOLL	QPOOL	LOAD	AUX	F	Renewabl
			MMBTU	MMBTU	MMBTU	MMBTU		kBtu/day
48.2	31	JAN	0.8	12.4	35.0	34.1	0.02	29.032
52.3	28	FEB	1.0	14.2	26.9	25.9	0.04	35.714
60.6	31	MAR	1.5	19.6	14.4	12.9	0.10	48.387
68.5	30	APR	1.7	21.8	1.8	0.0	0.99	60.000
74.3	31	MAY	2.0	24.5	0.0	0.0	1.00	0.000
80.2	30	JUN	2.4	26.5	0.0	0.0	1.00	0.000
83.3	31	JUL	2.7	28.2	0.0	0.0	1.00	0.000
83.5	31	AUG	2.7	26.3	0.0	0.0	1.00	0.000
78.1	30	SEP	2.4	21.1	0.0	0.0	1.00	0.000
69.3	31	OCT	2.0	18.1	7.4	5.3	0.28	67.742
59.4	30	NOV	1.3	13.3	22.3	21.0	0.06	43.333
51.1	31	DEC	0.9	11.6	34.2	33.3	0.03	29.032
		YR	21.5	237.6	141.8	132.5	0.07	

Table 3: Fchart output data

Table 40: Solar Thermal Analysis Flowchart (Table 3: F-Chart output data).

```
Path and name of input data file = dflt_fchart.prn
Value of no-data flag = -99
Column number of group field = 0
Value of valid group field = 1
Residual file needed (1 yes, 0 no) = 1
Model type (1:Mean,2:2p,3:3pc,4:3ph,5:4p,6:5p,7:MVR,8:HDD,9:CDD) = 4
Column number of dependent Y variable = 7
Number of independent X variables (0 to 6)  = 1
Column number of independent variable X1 = 1
Column number of independent variable X2 = 0
Column number of independent variable X3 = 0
Column number of independent variable X4 = 0
Column number of independent variable X5 = 0
Column number of independent variable X6 = 0
```

Table 4: Input into Inverse Modeling Toolkit

Table 41: Solar Thermal Analysis Flowchart (Table 4: Input into IMT).

```
SWIMMING POOL SOLAR SYSTEM

 ASHRAE INVERSE MODELING TOOLKIT (1.9)
********************************************
   Output file name = IMT.Out
********************************************
   Input data file name =  dflt_fchart.prn
   Model type =           4P
   Grouping column No =    0
   Value for grouping =    1
   Residual mode =         1
   # of X(Indep.) Var =    1
   Y1 column number =      2
   X1 column number =   1
   X2 column number =   0 (unused)
   X3 column number =   0 (unused)
   X4 column number =   0 (unused)
   X5 column number =   0 (unused)
   X6 column number =   0 (unused)
********************************************
   Regression Results
  --------------------------------------
         N =     12
  --------------------------------------
        R2 =     0.987
  --------------------------------------
     AdjR2 =     0.987
  --------------------------------------
      RMSE =      2.8479
  --------------------------------------
   CV-RMSE =     4.844%
  --------------------------------------
         p =     0.084
  --------------------------------------
        DW =     1.762 (p>0)
  --------------------------------------
        N1 =      8
  --------------------------------------
        N2 =      4
  --------------------------------------
       Ycp =     68.6995 (     10.3949)
  --------------------------------------
        LS =      1.6155 (      0.1069)
  --------------------------------------
        RS =      2.1659 (      0.3879)
  --------------------------------------
       Xcp =     74.3220 (      0.7060)
  --------------------------------------
 ---------------------------------
```

Table 5: Inverse Modeling toolkit output

Table 42: Solar Thermal Analysis Flowchart (Table 5: IMT output).

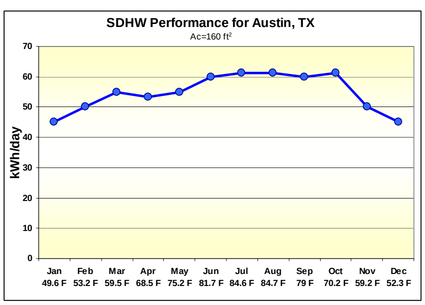


Figure 2: Renewable Energy Production

Figure 62: Solar Thermal Analysis Flowchart (Figure 2: Renewable Energy Production).

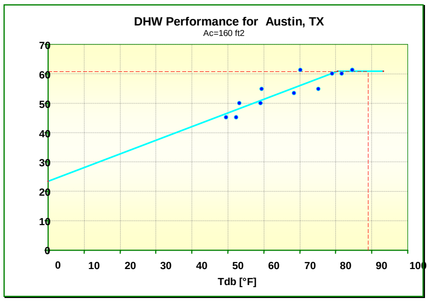


Figure 3: Output from Inverse Modeling Toolkit

Figure 63: Solar Thermal Analysis Flowchart (Figure 3: Output from IMT).

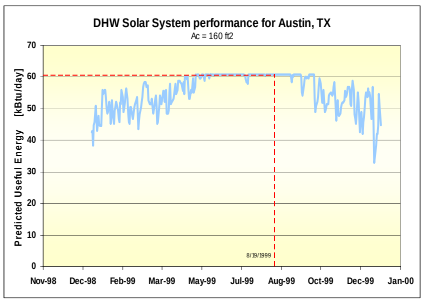


Figure 4: Annual and Peak Day Energy Savings

Figure 64: Solar Thermal Analysis Flowchart (Figure 4: Annual and Peak Day Energy Savings).

2.3.5.4 Wind Energy Input Screens

The user input screens for wind energy projects begin with the project input screen, as shown in Figure 65. When the user submits this type of project to the emissions calculator, they are directed to next screen shown in Figure 66. This input screen asks for specific information about the date when the wind energy system became operational. When the user completes the screen shown in Figure 66, they are redirected to the screen shown in Figure 67 where they are asked for 12 months of data from the project. When the user completes entering 12 months of data, they press the “done entering data” button and the project is submitted for analysis.

Figure 65: Wind Energy Systems Input Screens (Project Info).

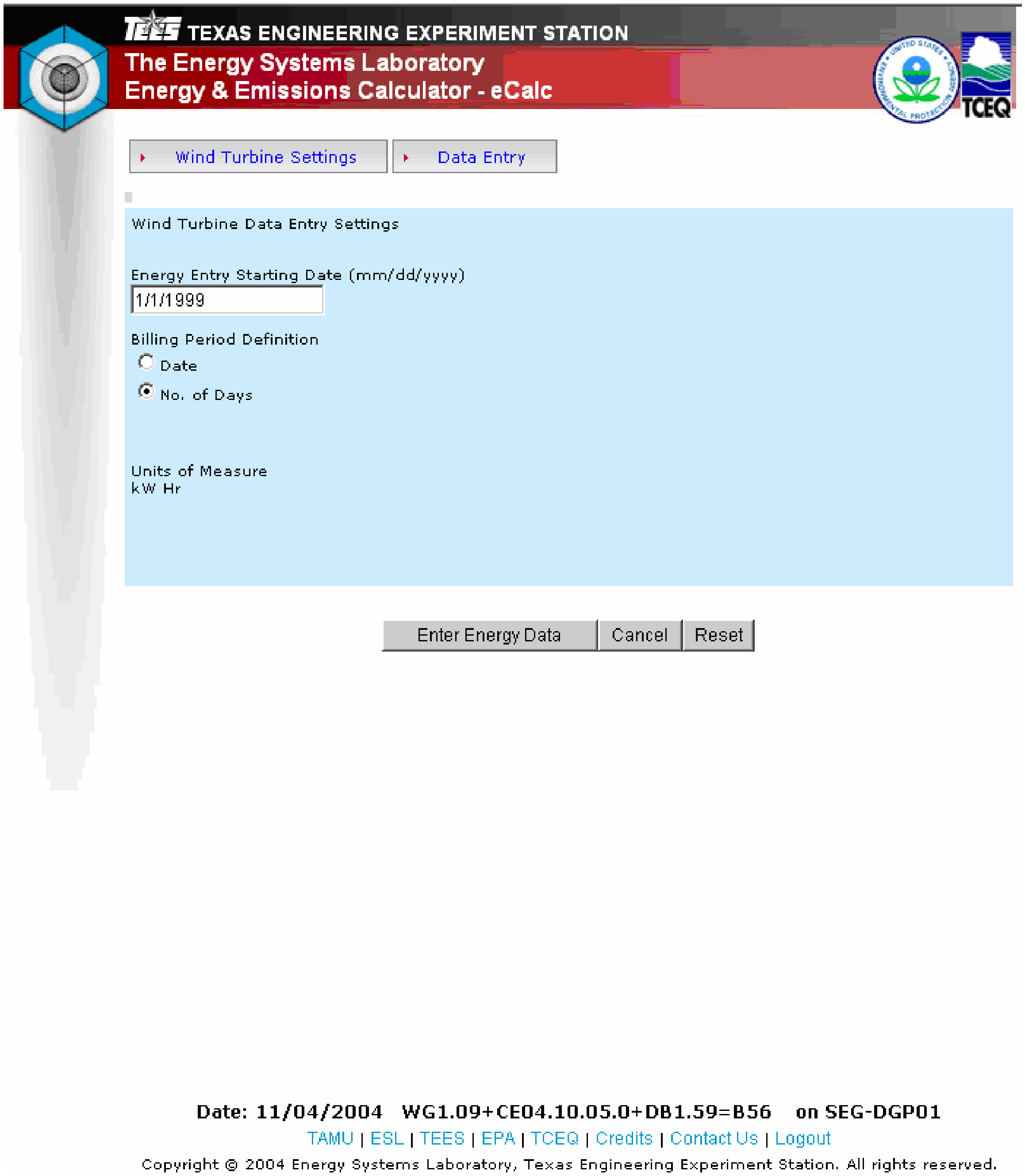


Figure 66: Wind Energy Systems Input Screens (Project Start Date Info).

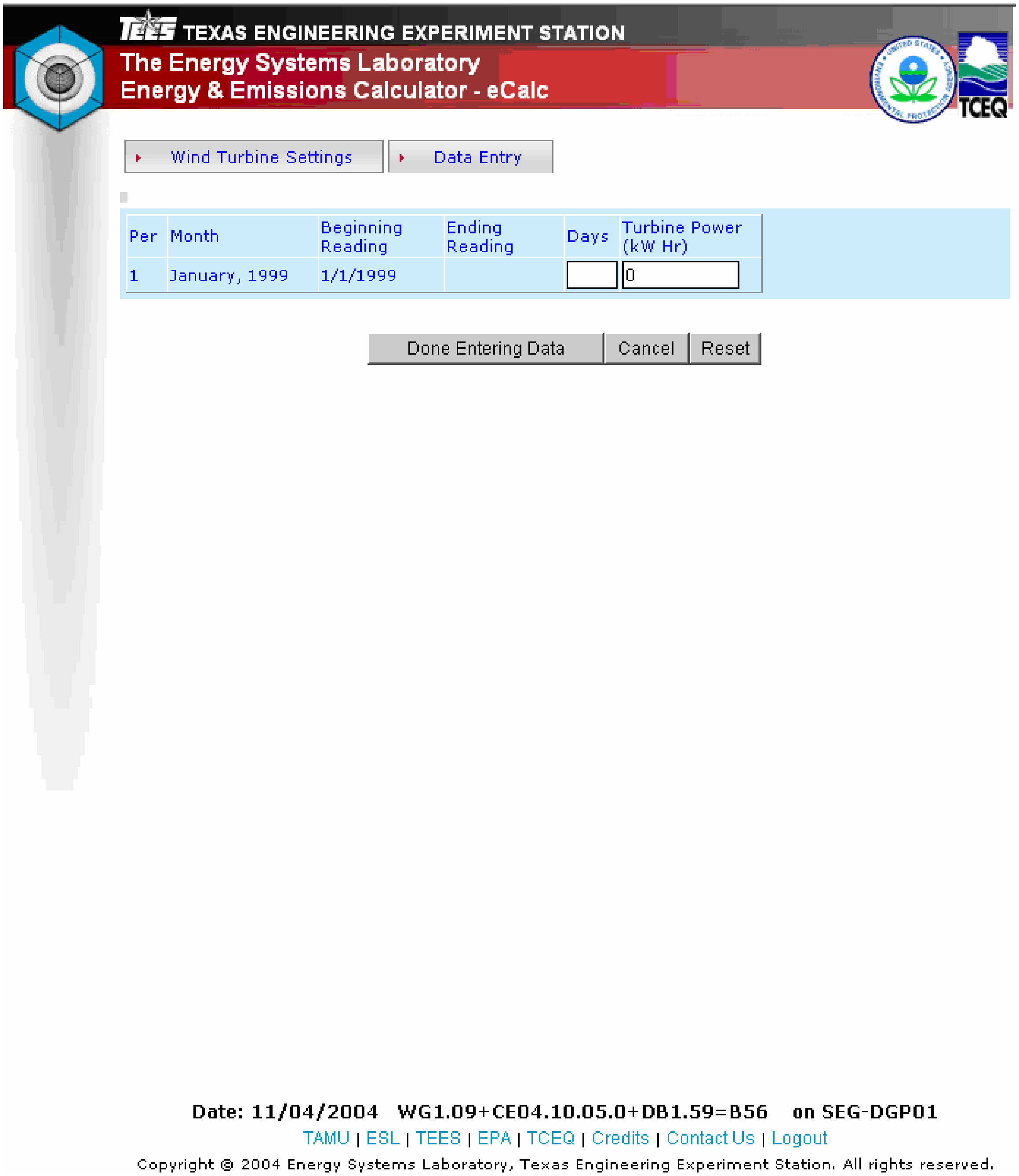


Figure 67: Wind Energy Systems Input Screens (Monthly Data Info).

2.3.5.5 Wind Energy Analysis Description

When the user submits their wind energy project for analysis, the emissions calculator performs a series of calculations, as indicated in Figure 68. For each analysis, the user is required to enter 12 months of wind energy production data, as shown in Table 43. To perform the appropriate weather normalization, ASHRAE's Inverse Model Toolkit (Kissock et al. 2002) is used to determine a statistical relationship between the wind-energy production and the local wind conditions during the coincident period using daily average NOAA weather data from the nearest weather location. As shown in Figure 69 and Figure 70, IMT produces coefficients (Table 44 and Table 45) that represent the electrical output of the wind turbine vs the average daily wind speed. These are then used to determine the annual wind production in 1999 and the 1999 peak day wind production for the Ozone Episode Day (August 19, 1999), as shown in Table 46.

In the next step of the analysis and in a similar fashion to the analysis shown for the residential simulation (Figure 10), the emissions calculator calculates the NOx, SOx, and CO_2 using the USEPA's eGRID database. These results are then reported by the emissions calculator in a format that is similar to that shown in Table 10 for residential and is emailed to the user as HTML and XML files.

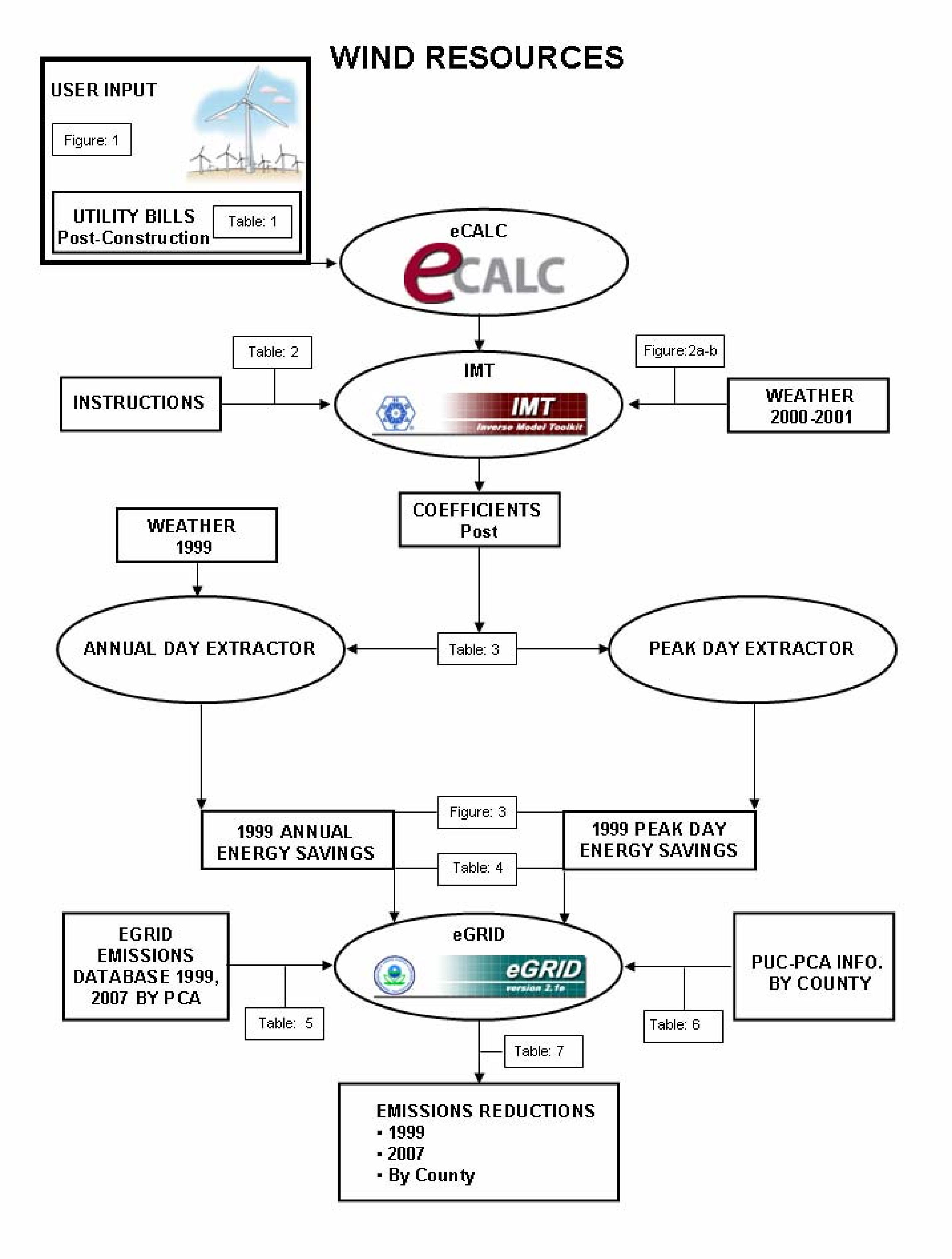


Figure 68: Wind Energy Analysis Flowchart.

12917_WT				
Start Date	End Date	Days	Energy Usage	Usage Per Period
10/1/2001	11/1/2001	31	**0.00**	**0.00**
11/1/2001	12/1/2001	30	**0.00**	**0.00**
12/1/2001	1/1/2002	31	**125.33**	**4.04**
1/1/2002	2/1/2002	31	**1725.05**	**55.65**
2/1/2002	3/1/2002	28	**1193.08**	**42.61**
3/1/2002	4/1/2002	31	**5564.37**	**179.50**
4/1/2002	5/1/2002	30	**968.68**	**32.29**
5/1/2002	6/1/2002	31	**2516.49**	**81.18**
6/1/2002	7/1/2002	30	**0.00**	**0.00**
7/1/2002	8/1/2002	31	**0.00**	**0.00**
8/1/2002	9/1/2002	31	**0.00**	**0.00**
9/1/2002	9/30/2002	29	**605.58**	**20.88**

Table 1: Post-Construction Data User Input

Table 43: Wind Energy Analysis Flowchart (Table 1: Post-Construction Data Input).

```
Line 1: Path and name of input data file = VBDD_WT_R.RES
Line 2: Value of no-data flag = -99
Line 3: Column number of group field = 0
Line 4: Value of valid group field = 0
Line 5: Residual file needed (1 yes, 0 no) = 0
Line 6: Model (1:Mean,2:2p,3:3pc,4:3ph,5:4p,6:5p,7:MVR,8:HDD,9:CDD) =
3
Line 7: Column number of dependent variable Y = 4
Line 8: Number of independent variables (0 to 6)  = 1
Line 9: Column number of independent variable X1 = 5
Line 10: Column number of independent variable X2 = 0
Line 11: Column number of independent variable X3 = 0
Line 12: Column number of independent variable X4 = 0
Line 13: Column number of independent variable X5 = 0
Line 14: Column number of independent variable X6 = 0
```

Table2: Example of I.M.T Instruction File

Table 44: Wind Energy Analysis Flowchart (Table 2: Example of IMT Instruction File).

```
*********************************************
 ASHRAE INVERSE MODELING TOOLKIT (1.9)
*********************************************
   Output file name = IMT.Out
*********************************************
   Input data file name =  VBDD_WT_R.RES
   Model type =           3P Cooling
   Grouping column No =    0
   Value for grouping =    0
   Residual mode =         0
   # of X(Indep.) Var =    1
   Y1 column number =      4
   X1 column number =   5
   X2 column number =   0 (unused)
   X3 column number =   0 (unused)
   X4 column number =   0 (unused)
   X5 column number =   0 (unused)
   X6 column number =   0 (unused)
*********************************************
   Regression Results
  --------------------------------------
         N =     12
  --------------------------------------
        R2 =     0.772
  --------------------------------------
     AdjR2 =     0.772
  --------------------------------------
      RMSE =     39.2409
  --------------------------------------
   CV-RMSE =    16.486%
  --------------------------------------
         p =    -0.204
  --------------------------------------
        DW =     2.336 (p>0)
  --------------------------------------
        N1 =      4
  --------------------------------------
        N2 =      8
  --------------------------------------
       Ycp =    167.7031 (      16.5544)
  --------------------------------------
        LS =      0.0000 (       0.0000)
  --------------------------------------
        RS =     74.4971 (      12.7884)
  --------------------------------------
       Xcp =     11.1728 (       0.0708)
  --------------------------------------
  ---------------------------------
        RS =      2.1659 (       0.3879)
  --------------------------------------
       Xcp =     74.3220 (       0.7060)
  --------------------------------------
      ---------------------------
```

Table3: Example of I.M.T Coefficients

Table 45: Wind Energy Analysis Flowchart (Table 3: Example of IMT Coefficients).

Results	12917	
	2P	3PC
Annual Sum	0	22284.22
OSD Sum	0	166.29
OSD Avg	0	4.89
OSD Peak	0	0.00
OSD Act. Peak	0	86.20

Table4: Examples of Energy Saving Outputs from Annual and Peak Day Extractor

Table 46: Wind Energy Analysis Flowchart (Table 4: Example of Energy Savings Output for Annual and Peak Day).

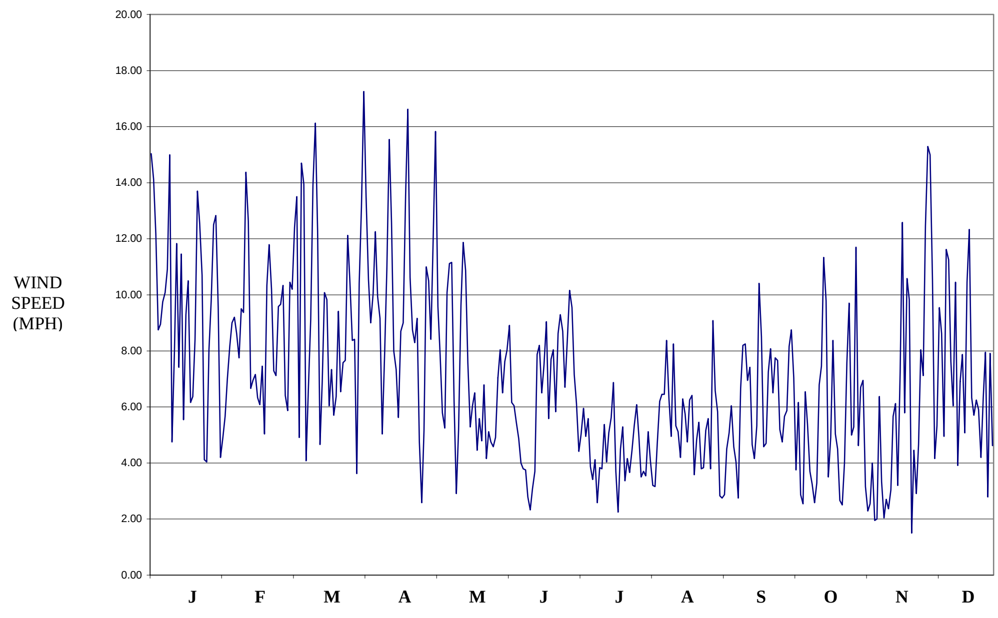


Figure 2a: Daily Report of Wind, 1999

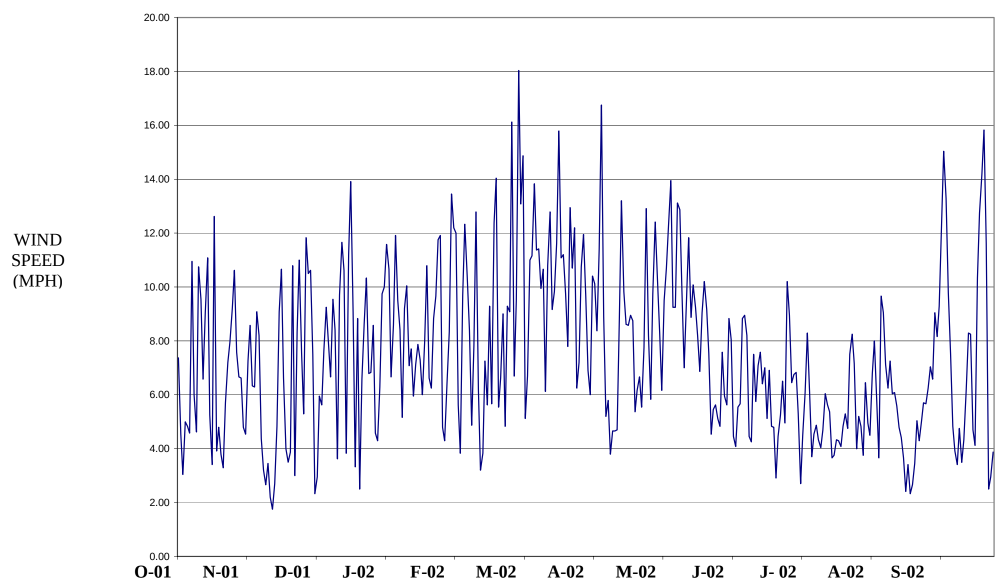


Figure 2b: Daily Report of Wind, 2001-2002

Figure 69: Wind Energy Analysis Flowchart (Figure 2a: 1999 Daily Wind Data, Figure 2b: 2001-2002 Wind Data).

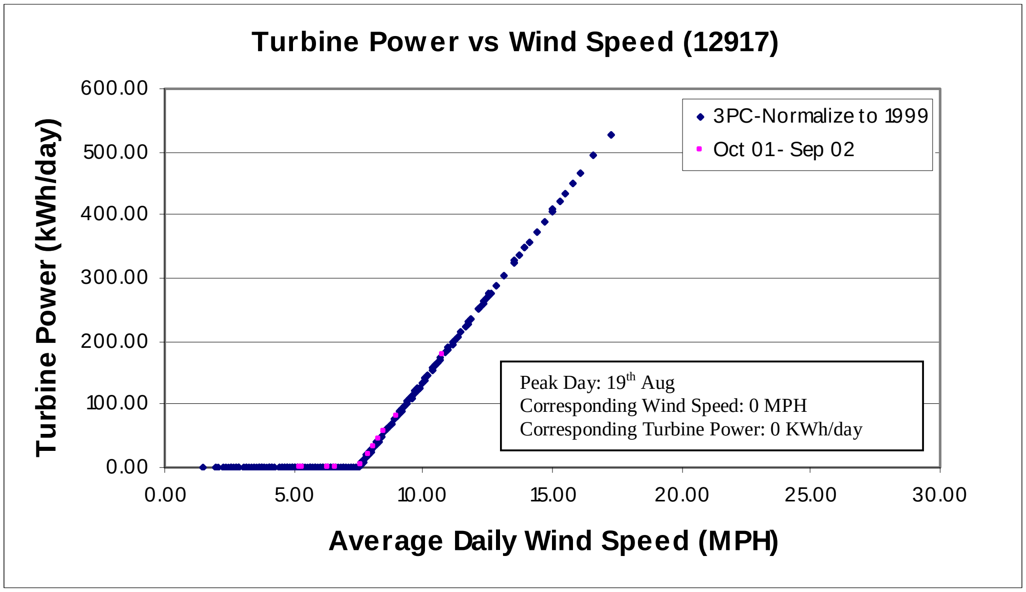


Figure 3: Chart showing Turbine power corresponding to Average Wind Speed

Figure 70: Wind Energy Analysis Flowchart (Figure 3: Plot of Wind Turbine Power vs Average Daily Wind Speed).

2.4 Literature Review and Uncertainty Analysis.

One of the requirements for the development of the emissions calculator was the need to document the analysis methods, including the history and peer-review of the analysis methods and the uncertainty of an analysis performed with the methods contained in the emissions calculator. To satisfy this requirement, a literature review and uncertainty analysis were performed on the F-Chart program, the PV F-Chart program, ASHRAE's Inverse Model Toolkit (IMT), Cool Roofs, and the U.S.D.O.E's DOE-2 program.

2.4.1 F-Chart Program

A review of the literature was conducted for the F-Chart program (Klein and Beckman 1983) that is used by the emissions calculator to calculate emissions reductions from solar thermal systems (Haberl and Cho 2004a). This review determined an uncertainty of F-Chart analysis methods by reviewing the published related accuracy of TRNSYS simulations versus measured data, F-Chart predictions versus measured data, F-Chart predictions versus TRNSYS simulations and F-Chart predictions versus other methods. This report begins with a review of the history of the F-Chart method and includes an example F-Chart calculation. In summary, from the literature it was found that hourly TRNSYS simulations versus measured data were shown to be within 5 to 6%, F-Chart predictions versus measured data showed agreement in the 2 to 15% range, and F-Chart predictions versus TRNSYS simulations were shown to vary from 1.1% to 4.7%. A significant number of studies used F-Chart to assess the accuracy of newly developed methods. In these studies, agreement varied from 2.5% to 9%.

2.4.2 PV F-Chart Program

A review of the literature was conducted for the PV F-Chart program (Klein and Beckman 1985) that is used by the emissions calculator to calculate emissions reductions from solar photovoltaic systems (Haberl and Cho 2004b). This report reviewed the reported uncertainty of the PV F-Chart analysis method by reviewing the published related accuracy of PV F-Chart analysis versus measured data, PV F-Chart predictions versus other methods, and PV F-Chart predictions versus TRNSYS simulations. This report contains a review of the history of the PV F-Chart method and includes an example PV F-Chart calculation. In summary, from the literature it was found that hourly PV F-Chart analysis versus measured data were shown to be within 4% of on-site measurement, PV F-Chart predictions versus TRNSYS simulations and another graphical method were also within 4% of annual values.

2.4.3 ASHRAE Inverse Model Toolkit

A review of the literature was conducted for ASHRAE's Inverse Model Toolkit (IMT) (Kissock et al. 2002) that is used by the emissions calculator to weather normalize monthly utility billing data, F-CHART and PV F-Chart analysis (Haberl and Cho 2004c). The report reviewed the published literature on the related accuracy of IMT and its algorithms versus other well-accepted statistical analysis tools, such as SAS. The report begins with a review of the history of the IMT, and the linear and change-point linear models. Then it reviews the published comparisons of the IMT and other analysis software, relying heavily on the accuracy testing that was performed as part of ASHRAE's Research Project 1050-RP. It also includes a detailed description of the basic algorithms and an example of the IMT weather-normalization analysis.

From the literature, it was found that the algorithms in the IMT almost exactly reproduce the same regression analysis one would get by running any one of the programs that it was compared against (i.e., usually to several significant digits). Four sets of accuracy and precision tests were performed as part of the testing for ASHRAE Research Project 1050-RP. The first set of tests was designed to test the accuracy and precision of IMT's computational and regression engines by comparing IMT results with results from the widely used SAS software. These tests showed that IMT's 1P and 2p and MVR models were accurate to two significant decimal figures, i.e., 99.99 % accurate or better. In the second set of tests, IMT 3P, 4P and 5P change-point model results were compared to model results from EModel. These tests also showed agreement to two significant figures, i.e., 99.99 % accurate or better. The third set of accuracy tests was designed to see how closely IMT change-point models could identify known change-points and slopes from synthetic data. The results of the third set of tests showed that IMT's 3PC, 3PH and 4P models were accurate to three significant figures, i.e., 99.999 % accurate or better. In the fourth set of accuracy tests, IMT's variable-base heating and cooling degree-day models were compared to PRISM HO and CO models. The results of the fourth set of tests showed agreement within 1% of the values calculated with PRISM.

In summary, in the case of IMT's 1P, 2P, 3P, 4P and MVR models, the program performs to within several significant decimal places to the same results from other widely accepted models. In the case of IMT's variable-based degree-day model, agreement is within 1% of the values reported by the Princeton Scorekeeping method (PRISM), which is considered acceptable since IMT and PRISM use different search algorithms for finding the change-point temperature, and both report results in units that require conversion prior to comparison. Therefore, it can be concluded that the IMT is accurate, when it is called upon to perform weather normalized regressions for modeling building energy use.

2.4.4 Cool Roofs

A review of the literature on cool roofs was performed (Haberl and Cho 2004d). In this literature review, seventy two (72) articles were reviewed from various sources, including: the literature compiled by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE); literature listed on the websites of the Florida Solar Energy Center (FSEC); the Oak Ridge National Laboratory (ORNL); the National Renewal Energy Laboratory (NREL); the Lawrence Berkeley National Laboratory (LBNL); the American Council for an Energy Efficient Economy (ACEEE); and the publications of Elsevier. Keywords searched were: cool roofs, radiant barrier, high-albedo, attic ventilation, duct, as well as the names of the most prolific authors in this area: Dr. Hashem Akbari (LBNL) and Mr. Danny Parker (FSEC).

Twenty-seven of seventy-two papers presented a quantitative cooling energy savings from cool roofs. In these twenty-seven articles, cooling energy savings varied from 2% to 44% and averaged about 20%. Ten papers presented quantitative savings as the percent (%) savings of peak cooling energy use, two papers mentioned heating energy savings, or additional amounts of heating required. The literature indicated that the peak cooling energy savings from cool roofs are between 3% and 35%, which depends on ceiling insulation levels, duct placement and attic configuration.

Heating energy savings of 11% through 19% were reported for radiant barrier systems, which can reduce heat fluxes and, as a result, can reduce heat loss to the attic and to the outside of a building in the winter weather condition. One paper reported heating savings of 50%, which was stated to be an impact of the roof re-covering, rather than the cool roof systems alone.

More than half (fifteen) of the papers showing energy savings from cool roofs implemented white roof systems. Eight papers used radiant barrier systems for cool roofs. The applications of the cool roof systems were performed on different building types; eighteen papers contained results from residential buildings and seven papers reported results from commercial buildings. No literature could be found on strictly industrial buildings that had quantitative savings. The literature reported that the implementation of cool roof systems was carried out in different climate conditions. However, most of these climates were in hot-humid zones of the United States.

Four of nine papers that reported quantitative results applied the white roof systems and showed heat flux reductions in the 20% to 72% range. Radiant barrier systems, used in four of the papers reviewed, had reduced heat gains from 8% to 98%. Photovoltaic roof systems were even utilized for cool roofs, and were reported to decrease cooling load by as much as 35% on a conventional roof. Applications for most of these papers were to residential buildings (seven of nine papers). One paper applied a white roof system to the commercial buildings along with the residential buildings.

Papers with qualitative analysis for the cool roof systems are also listed. Thirty-five papers showed cooling energy savings, two papers peak cooling savings, and five papers reported heating savings from cool roofs.

Applications were also mainly to the residential buildings; seventeen papers to the residential buildings, four papers to the commercial buildings, and two papers to the industrial buildings. Cooling energy savings were also mentioned from the papers that focused primarily on the urban heat island effect. These papers mentioned that the cool roof systems contribute to the reduction of the heat island effect.

2.4.5 DOE-2 Program

A review of the uncertainty of the DOE-2 simulation program by was performed by reviewing the published accuracy of DOE-2 simulations versus measured data (Empirical Validation), versus other simulation methods (Comparative Test), and versus analytical calculation (Analytical Verification) (Haberl and Cho 2004e). This report begins with a review of the history of the DOE-2 simulation program. In summary, from the literature it was found that DOE-2 simulations versus measured data were shown to be within 10% from 33 of 47 studies and within 26% from 14 of 47 studies, DOE-2 simulations versus simulations by other programs showed agreement in the 1% to 30% range (1% to 15% when weighted), and DOE-2 predictions versus analytical calculations were shown to vary from 0% to 5%. The sensitivity test revealed that DOE-2 versus analytical calculation was shown to be within 0.2% to 18.7%.

2.5 Weather data

In order to calculate the NOx emissions from energy efficiency and renewable energy (EE/RE) projects, several weather data sets needed to be assembled from the many weather sources in Texas (Figure 71 and Table 47), including hourly weather data sets needed for the DOE-2 simulations and daily average weather data for analysis that used monthly utility billing data.

To accomplish this, the counties were grouped according to the nearest TMY2 weather station as shown in Table 48. Next, for each group, weather files were determined for F-CHART, PV F-CHART, ASHRAE 90.1-1989, and ASHRAE 90.1-1999 analysis. Finally, as shown in Table 49, weather files were assigned for NOAA data (i.e., temperature, humidity, wind speed) and NREL (i.e., solar radiation). In some instances, where solar radiation data were not available from the NREL database, TCEQ solar data were used. For NREL solar sources, solar data included global horizontal, direct normal beam, and diffuse solar radiation. For TCEQ solar sources, only global horizontal solar radiation data were available which required synthesis of direct normal beam and diffuse radiation using an iterative kt procedure (Erbs 1982). Synthetic beam and diffuse solar data were also used to fill missing NREL data.

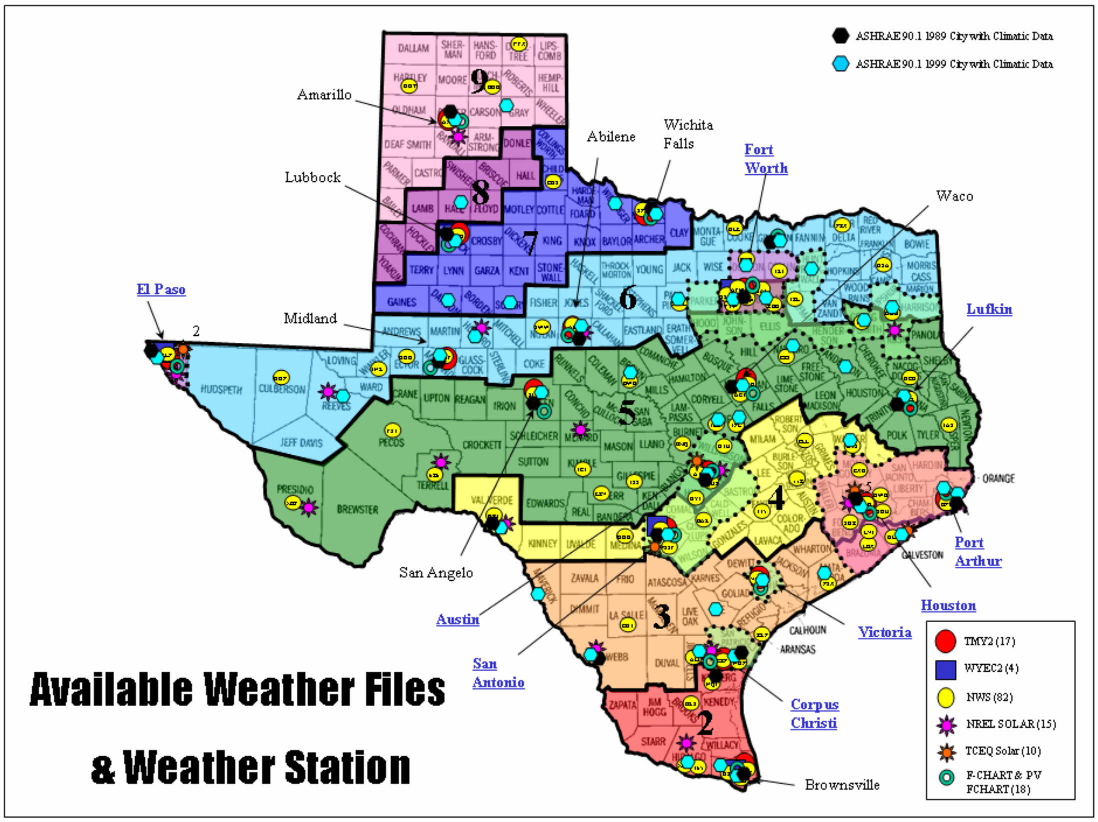


Figure 71: Available Weather Stations in Texas.

List of Available Weather Files and Weather Stations of Texas

Texas Weather Stations (NOAA)

1	Abilene Regional Airport (ABI)
2	Alice International Airport (ALI)
3	Amarillo International Airport (AMA)
4	Angleton / Lake Jackson Brazori (LBX)
5	Arlington Municipal Airport (GKY)
6	Austin - Bergstrom International (AUS)
7	Austin Camp Mabry (ATT)
8	Borger Hutchinson County Airport (BGD)
9	BRENHAM: BRENHAM MUNICIPAL AIRPORT (11R)
10	Brownsville S Padre Isl International (BRO)
11	BROWNWOOD: BROWNWOOD REGIONAL AIRPORT (BWD)
12	Burnet Municipal Airport (BMQ)
13	Childress Municipal Airport (CDS)
14	College Station (CLL)
15	Conroe Montgomery County Airport (CXO)
16	Corpus Christi International Airport (CRP)
17	CORPUS CHRISTI: CORPUS CHRISTI NAS/TRUAX FIELD ARPT (NGP)
18	Corsicana Campbell Field (CRS)
19	Cotulla La Salle Co Airport (COT)
20	Dalhart Municipal Airport (DHT)
21	Dallas - Fort Worth International Airport (DFW)
22	Dallas Love Field (DAL)
23	Dallas Redbird Airport (RBD)
24	Del Rio International Airport (DRT)
25	Denton Municipal Airport (DTO)
26	Dryden Terrell County Airport (6R6)
27	El Paso International Airport (ELP)
28	FALFURRIAS : BROOKS COUNTY AIRPORT (BKS)
29	Fort Stockton Pecos County Airport (FST)
30	Fort Worth Alliance Airport (AFW)
31	Fort Worth Meacham (FTW)
32	FREDERICKSBURG: GILLESPIE COUNTY AIRPORT (T82)
33	GAINESVILLE : GAINESVILLE MUNICIPAL AIRPORT (GLE)
34	Galveston Scholes Field (GLS)
35	GEORGETOWN : GEORGETOWN MUNICIPAL AIRPORT (GTU)
36	Harlingen Rio Grande Valley I (HRL)
37	Hondo Municipal Airport (HDO)
38	Houston Bush Intercontinental (IAH)
39	Houston Clover Field (LVJ)
40	Houston Hooks Memorial Airport (DWH)
41	Houston Sugarland Mem (SGR)
42	Houston William P Hobby Airport (HOU)
43	Huntsville Municipal Airport (UTS)
44	JASPER : JASPER COUNTY-BELL FIELD AIRPORT (JAS)
45	Junction Kimble County Airport (JCT)
46	KERRVILLE : KERRVILLE MUNI/LOUIS SCHREINER FLD AIRPORT (ERV)
47	KILLEEN : KILLEEN MUNICIPAL AIRPORT (ILE)
48	KINGSVILLE : KINGSVILLE NAS AIRPORT (NQI)
49	LA GRANGE : FAYETTE REGIONAL AIR CENTER AIRPORT (3T5)
50	Longview E Tx Rgnl Airport (GGG)
51	Lubbock International Airport (LBB)
52	Lufkin Angelina Cty Airport (LFK)
53	MARFA : MARFA MUNICIPAL AIRPORT (MRF)
54	McAllen Miller International Airport (MFE)
55	McKinney Municipal Airport (TKI)
56	Midland International Airport (MAF)
57	Mineral Wells Airport (MWL)
58	MOUNT PLEASANT : MOUNT PLEASANT REGIONAL AIRPORT (OSA)
59	NACOGDOCHES : A L MANGHAM JR REGIONAL AIRPORT (OCH)
60	New Braunfels Municipal Airport (BAZ)
61	Odessa Schlemeyer Field (ODO)
62	Palacios Municipal Airport (PSX)
63	PARIS : COX FIELD AIRPORT (PRX)
64	PERRYTON : PERRYTON OCHILTREE COUNTY AIRPORT (PYX)
65	Pine Springs Guadalupe Mountn (GDP)
66	Port Arthur Se Tx Rgnl Airport (BPT)
67	Port Isabel Cameron County Airport (PIL)
68	Rockport Aransas Co Airport (RKP)
69	San Angelo Mathis Field (SJT)
70	San Antonio International Airport (SAT)
71	San Antonio Stinson Municipal Airport (SSF)
72	SAN MARCOS : SAN MARCOS MUNICIPAL AIRPORT (HYI)
73	SWEETWATER : AVENGER FIELD AIRPORT (SWW)
74	TEMPLE: DRAUGHON-MILLER CNTRL TEXAS REGIONAL ARPT (TPL)
75	Terrell Municipal Airport (TRL)
76	Tyler Pounds Field (TYR)
77	Victoria Regional Airport (VCT)
78	WACO : MC GREGOR EXECUTIVE AIRPORT (PWG)
79	Waco Regional Airport (ACT)
80	WESLACO : MID VALLEY AIRPORT (T65)
81	Wichita Falls Municipal Airport (SPS)
82	Wink Winkler Co Airport (INK)

Texas TMY2 Weather Files

1	Abilene
2	Amarillo
3	Austin
4	Brownsville
5	Corpus Christi
6	El Paso
7	Fort Worth
8	Houston
9	Lubbock
10	Lufkin
11	Midland
12	Port Arthur
13	San Angelo
14	San Antonio
15	Victoria
16	Waco
17	Wichita Falls

Texas WYEC2 Weather Files

1	El Paso
2	Brownsville
3	Fort Worth
4	San Antonio

NREL Solar Stations

1	Abilene
2	Austin
3	Big Spring
4	Canyon
5	Clear Lake
6	Corpus Christi
7	Del Rio
8	Edinburg
9	El Paso
10	Laredo
11	Menard
12	Overton
13	Pecos
14	Presidio
15	Sanderson

TCEQ Solar Stations

1	Bexar
2	Travis
3	El Paso (2)
4	Galveston
5	Harris (5)

FCHART and PV FCHART (New Weather File)

1	ABILENE
2	AMARILLO
3	AUSTIN
4	BROWNSVILLE
5	CORPUS CHRISTI
6	EL PASO
7	FORT WORTH
8	HOUSTON
9	LUBBOCK
10	LUFKIN
11	MIDLAND-ODESSA
12	PORT ARTHUR
13	SAN ANGELO
14	SAN ANTONIO
15	SHERMAN
16	VICTORIA
17	WACO
18	WICHITA FALLS

Table 47: List of Available Weather Files in Texas (Listed by Symbol).

Area	No.	County	NOAA Weather Station		Solar Station		TMY2		FCHART		PV-FCHART		DOE Include File	Weather File	DOE TRY weather file name	East or West Texas	Climate Zone	HDD		CDD		AHSRAE 90.1-1989		AHSRAE 90.1-1999		County
			WBAN No.	Weather Station	Source	File	WBAN No.	File										1989	1999	1989	1999	Nearest City	Table 8A (10, 12, 16)	Nearest City	Table B (5, 6, 8, 10)	
	ID	County	WBAN No.	Weather Station	x	x	x	TMY2File	Fchart	FchartID	PVFChart	PVFChartID	DOE_INC	x	DOE_WF	PRECODE	CZ									County
Austin	22	Bastrop	13958	Austin Camp Mabry (ATT)	NREL	Austin	13958	Austin	Austin	14	Austin	18	BAS	Austin	ATT	West	4					Austin	12	Austin	6	Bastrop
	26	Caldwell	13958	Austin Camp Mabry (ATT)	NREL	Austin	13958	Austin	Austin	14	Austin	18	CAL	Austin	ATT	West	4					Austin	12	Austin	6	Caldwell
	8	Hays	13958	Austin Camp Mabry (ATT)	NREL	Austin	13958	Austin	Austin	14	Austin	18	HAY	Austin	ATT	West	5					Austin	12	Austin	6	Hays
	40	Travis	13958	Austin Camp Mabry (ATT)	NREL	Austin	13958	Austin	Austin	14	Austin	18	TRA	Austin	ATT	West	5	1735	1688	6873	7171	Austin	12	Austin	6	Travis
	41	Williamson	13958	Austin Camp Mabry (ATT)	NREL	Austin	13958	Austin	Austin	14	Austin	18	WLL	Austin	ATT	West	5					Austin	12	Kileen/Robert-gray or **Austin**	6	Williamson
Corpus	38	Nueces	12924	Corpus Christi International Airport (CRP)	NREL	Corpus Christi	12924	Corpus Christi	Corpus Christi	52	Corpus Christi	58	NUE	Corpus Christi	CRP	East	3	889	1016	8200	8023	Corpus Christi	16	Corpus Christi or Alice	5	Nueces
	15	San Patricio	12924	Corpus Christi International Airport (CRP)	NREL	Corpus Christi	12924	Corpus Christi	Corpus Christi	52	Corpus Christi	58	SAP	Corpus Christi	CRP	East	3					Corpus Christi	16	Corpus Christi or Alice	5	San Patricio
El Paso	30	El Paso	23044	El Paso International Airport (ELP)	TCEQ	C12-El Paso UTEP	23044	El Paso	El Paso	68	El Paso	70	ELP	El Paso	ELP	West	6	2605	2708	5617	5488	El Paso	12	El Paso	10	El Paso
Dallas-Ft. Worth	27	Collin	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	COL	Fort Worth	DFW	West	6					Sherman or Fort Worth	12	**Denton,** Greenville or Sherman	8	Collin
	4	Dallas	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	DAL	Fort Worth	DFW	West	5		2259		6587	Fort Worth	12	Dallas	8	Dallas
	29	Denton	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	DEN	Fort Worth	DFW	West	6					Shermanor Fort Worth	12	Denton	8	Denton
	31	Ellis	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	ELL	Fort Worth	DFW	West	5					Fort Worth	12	Fort Worth, Dallas or Corsicana	8	Ellis
	23	Hood	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	HOD	Fort Worth	DFW	West	5					Fort Worth	12	Mineral Wells or Fort Worth	8	Hood
	24	Hunt	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	HNT	Fort Worth	DFW	West	6					Shermanor Fort Worth	12	Greenville	10	Hunt
	36	Johnson	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	JOH	Fort Worth	DFW	West	5					Fort Worth	12	Mineral Wells or Fort Worth	8	Johnson
	10	Kaufman	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	KAU	Fort Worth	DFW	West	6					Fort Worth	12	Greenville, **Dallas** or Corsicana	8	Kaufman
	39	Parker	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	PAR	Fort Worth	DFW	West	6					Fort Worth	12	Mineral Wells or Fort Worth	8	Parker
	13	Rockwall	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	ROC	Fort Worth	DFW	West	6					Shermanor Fort Worth	12	**Dallas** or Greeenville	8	Rockwall
	17	Tarrant	03927	Dallas - Fort Worth International Airpor (DFW)	NREL	Overton	03927	Fort Worth	Fort Worth	78	Fort Worth	83	TAR	Fort Worth	DFW	West	5	2354		6174		Fort worth	12	Fort worth	8	Tarrant
Houston/Galveston	2	Brazoria	12960	Houston Bush Intercontinental (IAH)	NREL	Clear Lake	12960	Houston	Houston	96	Houston	102	BRA	Houston	IAH	East	3					Houston	10	Houston, Galveston or Bay City	5	Brazoria
	5	Fort Bend	12960	Houston Bush Intercontinental (IAH)	NREL	Clear Lake	12960	Houston	Houston	96	Houston	102	FOB	Houston	IAH	East	4					Houston	10	Houston or Bay City	5	Fort Bend
	32	Galveston	12960	Houston Bush Intercontinental (IAH)	NREL	Clear Lake	12960	Houston	Houston	96	Houston	102	GAL	Houston	IAH	East	3		1263		7378	Houston	10	Galveston	5	Galveston
	34	Harris	12960	Houston Bush Intercontinental (IAH)	NREL	Clear Lake	12960	Houston	Houston	96	Houston	102	HAR	Houston	IAH	East	4	1346	1371	7125	7357	Houston	10	Houston	5	Harris
	37	Montgomery	12960	Houston Bush Intercontinental (IAH)	NREL	Clear Lake	12960	Houston	Houston	96	Houston	102	MOG	Houston	IAH	East	4					Houston	10	Huntsville or **Houston**	5	Montgomery
	20	Waller	12960	Houston Bush Intercontinental (IAH)	NREL	Clear Lake	12960	Houston	Houston	96	Houston	102	WAL	Houston	IAH	East	4					Houston	10	Houston	5	Waller
Tyler/Longview	33	Gregg	03901	Longview E Tx Rgnl Airport (GGG)	NREL	Overton	93987	Lufkin	Lufkin	125	Lufkin	131	GRE	Lufkin	GGG	East	6					Lufkin	12	Longview	8	Gregg
	35	Harrison	03901	Longview E Tx Rgnl Airport (GGG)	NREL	Overton	93987	Lufkin	Lufkin	125	Lufkin	131	HAN	Lufkin	GGG	East	6					Lufkin	12	Longview	8	Harrison
	9	Henderson	03901	Longview E Tx Rgnl Airport (GGG)	NREL	Overton	93987	Lufkin	Lufkin	125	Lufkin	131	HDS	Lufkin	GGG	East	5					Lufkin, Waco or Fort Worth	12	Tyler, Palestine or Corsicana	8	Henderson
	14	Rusk	03901	Longview E Tx Rgnl Airport (GGG)	NREL	Overton	93987	Lufkin	Lufkin	125	Lufkin	131	RUS	Lufkin	GGG	East	5					Lufkin	12	Tyler or Longview	8	Rusk
	16	Smith	03901	Longview E Tx Rgnl Airport (GGG)	NREL	Overton	93987	Lufkin	Lufkin	125	Lufkin	131	SMI	Lufkin	GGG	East	5		1296		6562	Lufkin	12	Tyler	8	Smith
	18	Upshur	03901	Longview E Tx Rgnl Airport (GGG)	NREL	Overton	93987	Lufkin	Lufkin	125	Lufkin	131	UPS	Lufkin	GGG	East	6					Lufkin	12	Tyler or Longview	8	Upshur
Beaumont Pt. Arthur	3	Chambers	12917	Port Arthur Se Tx Rgnl Airport (BPT)	TCEQ	C34-Galveston Airport	12917	Port Arthur	Port Arthur	166	Port Arthur	172	CHA	Port Arthur	BPT	East	4					Houston or Port Arthur	10	Beaumont or **Houston**	5	Chambers
	7	Hardin	12917	Port Arthur Se Tx Rgnl Airport (BPT)	TCEQ	C34-Galveston Airport	12917	Port Arthur	Port Arthur	166	Port Arthur	172	HAD	Port Arthur	BPT	East	4					Port Arthur	10	Beaumont	6	Hardin
	25	Jefferson	12917	Port Arthur Se Tx Rgnl Airport (BPT)	TCEQ	C34-Galveston Airport	12917	Port Arthur	Port Arthur	166	Port Arthur	172	JEF	Port Arthur	BPT	East	4	1416	1677	6888	6703	Port Arthur	10	Beaumont	6	Jefferson
	11	Liberty	12917	Port Arthur Se Tx Rgnl Airport (BPT)	TCEQ	C34-Galveston Airport	12917	Port Arthur	Port Arthur	166	Port Arthur	172	LIB	Port Arthur	BPT	East	4					Houston or Port Arthur	10	Beaumont, Galveston or **Houston**	5	Liberty
	12	Orange	12917	Port Arthur Se Tx Rgnl Airport (BPT)	TCEQ	C34-Galveston Airport	12917	Port Arthur	Port Arthur	166	Port Arthur	172	ORA	Port Arthur	BPT	East	4					Port Arthur	10	Beaumont	6	Orange
San Antonio	1	Bexar	12921	San Antonio International Airport (SAT)	TCEQ	C58-Camp Bullis	12921	San Antonio	San Antonio	187	San Antonio	194	BEX	San Antonio	SAT	West	4	1579	1644	7170	7142	San Antonio	12	San Antonio	6	Bexar
	28	Comal	12921	San Antonio International Airport (SAT)	TCEQ	C58-Camp Bullis	12921	San Antonio	San Antonio	187	San Antonio	194	COM	San Antonio	SAT	West	4					San Antonio	12	San Antonio	6	Comal
	6	Guadalupe	12921	San Antonio International Airport (SAT)	TCEQ	C58-Camp Bullis	12921	San Antonio	San Antonio	187	San Antonio	194	GUA	San Antonio	SAT	West	4					San Antonio	12	San Antonio	6	Guadalupe
	21	Wilson	12921	San Antonio International Airport (SAT)	TCEQ	C58-Camp Bullis	12921	San Antonio	San Antonio	187	San Antonio	194	WIL	San Antonio	SAT	West	4					San Antonio	12	San Antonio	6	Wilson
Victoria	19	Victoria	12912	Victoria Regional Airport (VCT)	TCEQ	C58-Camp Bullis	12912	Victoria	Victoria	347	Victoria	225	VIC	Victoria	VCT	East	3	Hou	1296	Hou	7507			Victoria	5	Victoria

Table 48: Assignment of Weather Stations by County (NOAA, TMY2, F-CHART, PV F-CHART, NAHB, Climate Zone, HDD, CDD, 90.1-1989, 90.1-1999).

County No.	County	Affected - A Non Attain - N Others - O	NOAA WBAN No.	NOAA	Lat Deg.	Lat Min.	Long Deg.	Long Min.	Elev. (m)	NREL Station No.	NREL	TCEQ CAMS No.	TCEQ	Lat Deg.	Lat Min.	Long Deg.	Long Min.	Elev. (m)	ESL Site No.	ESL	TMY2 WBAN No.	TMY2	Latitude Deg.	Latitude Min.	Longitude Deg.	Longitude Min.	Elev. (m)
1	Bastrop	A																			13958	Austin	N30	18	W97	42	189
2	Bexar	A	12921	San Antonio International Airport (SAT)	N29	32	W98	28	246.3			C58	Camp Bullis	N29	38	W98	34		140	UTHSC	12921	San Antonio	N29	32	W98	28	242
2	Bexar	A	12970	San Antonio Stinson Municipal Airport (SSF)	N29	20	W98	28	175.3												12922	San Antonio	N29	32	W98	28	242
3	Caldwell	A																			13968	Austin	N30	18	W97	42	189
4	Comal	A																			12923	San Antonio	N29	32	W98	28	242
5	Ellis	A										C30	El Paso East	N31	45	W106	25				03936	Fort Worth	N32	50	W97	3	164
5	Ellis	A										C94	Midlothian Tower	N32	26	W97	1				03937	Fort Worth	N32	50	W97	3	164
6	Gregg	A	03901	Longview E. Texas Rgnl Airport (GGG)	N32	23	W94	43	111.3												93987	Lufkin	N31	14	W94	45	96
7	Guadalupe	A	12971	New Braunfels Municipal Airport (BAZ)	N29	43	W98	3	196.3												12924	San Antonio	N29	32	W98	28	242
8	Harrison	A																			93988	Lufkin	N31	14	W94	45	96
9	Hays	A	-	SAN MARCOS : SAN MARCOS MUNICIPAL AIRPORT (HYI)	-	-	-	-	-												93999	Lufkin	N31	14	W94	45	96
10	Johnson	A										C77	Cleburne Airport	N32	21	W97	26				03930	Fort Worth	N32	50	W97	3	164
11	Kaufman	A	53911	Terrell Municipal Airport (TRL)	N32	43	W96	16	144.3			C71	Kaufman	N32	34	W96	15				03939	Fort Worth	N32	50	W97	3	164
12	Nueces	A	12924	Corpus Christi International Airport (CRP)	N27	46	W97	31	12.5	6	Corpus Christi	C4	Corpus Christi West	N27	46	W97	26				12924	Corpus Christi	N27	46	W97	30	13
12	Nueces	A	-	CORPUS CHRISTI : CORPUS CHRISTI NAS/TRUAX FIELD ARPT (NGP)	-	-	-	-	-												12924	Corpus Christi	N27	46	W97	30	13
13	Parker	A										C76	Parker County (Fort Worth)	N32	52	W97	54				03940	Fort Worth	N32	50	W97	3	164
14	Rockwall	A										C69	Rockwall Heath	N32	56	W96	26				03941	Fort Worth	N32	50	W97	3	164
15	Rusk	A								12	Overton										93987	Lufkin	N31	14	W94	45	96
16	San Patricio	A																			12924	Corpus Christi	N27	46	W97	30	13
17	Smith	A	13972	Tyler Pounds Field (TYR)	N32	21	W95	24	165.3			C82	Tyler Airport relocated	N32	21	W95	25				93900	Lufkin	N31	14	W94	45	96
18	Travis	A	13904	Austin - Bergstrom International (AUS)	N30	11	W97	41	146.3	2	Austin	C38	Austin Audubon Society	N30	29	W97	52		202	S.F. Austin Building (SFA)	93990	Lufkin	N31	14	W94	45	96
18	Travis	A	13958	Austin Camp Mabry (ATT)	N30	19	W97	46	200.3										217	Rober E. Johnson Elec Rcom. (West Solar)	93991	Lufkin	N31	14	W94	45	96
18	Travis	A																	217	Rober E. Johnson Elec Rcom. (South Solar)	93992	Lufkin	N31	14	W94	45	96
19	Upshur	A																			93989	Lufkin	N31	14	W94	45	96
20	Victoria	A	12912	Victoria Regional Airport (VCT)	N28	51	W96	55	35.1			C87	Victoria	N28	50	W97	0				12912	Victoria	N28	51	W96	55	32
21	Williamson	A	-	GEORGETOWN : GEORGETOWN MUNICIPAL AIRPORT (GTU)	-	-	-	-	-												93993	Lufkin	N31	14	W94	45	96
22	Wilson	A																			12925	San Antonio	N29	32	W98	28	242
23	Henderson	A																									
24	Hood	A										C73	Granbury	N32	27	W97	46										
25	Hunt	A										C1005	Greenville	N33	9	W96	7										
26	Brazoria	N	12976	Angleton / Lake Jackson Brazoria (LBX)	N29	7	W95	28	7.6			C1015	Lake Jackson	N29	3	W95	28				12960	Houston	N29	59	W95	22	33
26	Brazoria	N	12975	Houston Clover Field (LVJ)	N29	31	W95	15	13.4												12960	Houston	N29	59	W95	22	33
27	Chambers	N																			12917	Port Arthur	N29	57	W94	1	7
28	Collin	N	53914	McKinney Municipal Airport (TKI)	N33	11	W96	35	176.3			C31	Frisco C31	N33	8	W96	47				03937	Fort Worth	N32	50	W97	3	164
28	Collin	N										C68	Anna	N33	21	W96	33				03938	Fort Worth	N32	50	W97	3	164
29	Dallas	N	13960	Dallas Love Field (DAL)	N32	51	W96	51	134.1			C63	Dallas North #2 (Dallas)	N32	55	W96	48		794	Federal Reserve - Weather Station (FRW)	03927	Fort Worth	N32	50	W97	3	164
29	Dallas	N	03971	Dallas Redbird Airport (RBD)	N32	41	W96	52	200.3			C74	Sunnyvale Long Creek (Dallas)	N32	46	W96	33				03928	Fort Worth	N32	50	W97	3	164
29	Dallas	N										C401	Dallas Hinton St	N32	49	W96	52				03929	Fort Worth	N32	50	W97	3	164
30	Denton	N	03991	Denton Municipal Airport (DTO)	N33	12	W97	12	195.7			C56	Denton Airport South	N33	12	W97	11				03942	Fort Worth	N32	50	W97	3	164
31	El Paso	N	23044	El Paso International Airport (ELP)	N31	49	W106	23	1194.2	9	El Paso	C12	El Paso JTEP	N31	46	W106	30		325	Valle Verde Campus (ECV)	23044	El Paso	N31	48	W106	24	1194
31	El Paso	N										C37	Ascarate Park SE	N31	46	W106	24				23045	El Paso	N31	48	W106	24	1194
31	El Paso	N										C41	El Paso Chamizal	N31	46	W106	27				23046	El Paso	N31	48	W106	24	1194
32	Fort Bend	N	12977	Houston Sugarland Mem. (SGR)	N29	37	W95	39	25.0												12969	Houston	N29	59	W95	22	33
33	Galveston	N	12923	Galveston Scholes Field (GLS)	N29	16	W94	52	1.5			C34	Galveston Airport	N29	16	W94	51				12960	Houston	N29	59	W95	22	33
34	Hardin	N																			12918	Port Arthur	N29	57	W94	1	7
35	Harris	N	12960	Houston Bush Intercontinental (IAH)	N29	59	W95	22	29.0	5	Clear Lake	C8	Aldine	N29	54	W95	20		121	UT Health Science Center	12960	Houston	N29	59	W95	22	33
35	Harris	N	53910	Houston Hooks Memorial Airport (DWH)	N30	4	W95	33	46.3			C15	Channelview	N29	48	W95	8		931	Habitat Humanity Houses	12960	Houston	N29	59	W95	22	33
35	Harris	N	12918	Houston William P Hobby Airport (HOU)	N29	38	W95	17	13.4			C26	Northwest Harris County	N30	2	W95	40				12960	Houston	N29	59	W95	22	33
35	Harris	N										C35	Deer Park #2	N29	40	W95	8				12961	Houston	N29	59	W95	22	33
35	Harris	N										C45	Seabrook Friendship Park	N29	35	W95	1				12962	Houston	N29	59	W95	22	33
35	Harris	N										C53	Houston Bayland Park	N29	42	W95	30				12963	Houston	N29	59	W95	22	33
35	Harris	N										C81	Houston Regional Office	N29	44	W95	15				12964	Houston	N29	59	W95	22	33
35	Harris	N										C85	Karnack	N32	40	W94	10				12965	Houston	N29	59	W95	22	33
35	Harris	N										C403	Clinton (CCEC, Houston)	N29	44	W95	15				12966	Houston	N29	59	W95	22	33
35	Harris	N										C617	Wallisville Road	N29	49	W94	[illegible]				12967	Houston	N29	59	W95	22	33
35	Harris	N										C1015	Lynchburg Ferry	N29	46	W95	5				12968	Houston	N29	59	W95	22	33
36	Jefferson	N	12917	Port Arthur Se Tx Rgnl Airport (BPT)	N29	57	W94	1	4.9			C28	Port Arthur West	N29	54	W93	[illegible]				12919	Port Arthur	N29	57	W94	1	7
36	Jefferson	N										C2	Beaumont Downtown	N30	2	W94	4				12920	Port Arthur	N29	57	W94	1	7
36	Jefferson	N										C64	Hamshire	N29	52	W94	[illegible]				12921	Port Arthur	N29	57	W94	1	7
36	Jefferson	N										C643	SETRPC 43 Jefferson County Airport	N29	57	W94	0	0			12922	Port Arthur	N29	57	W94	1	7
37	Liberty	N																			12923	Port Arthur	N29	57	W94	1	7
38	Montgomery	N	53902	Conroe Montgomery County Airport (CXO)	N30	21	W95	25	74.7			C78	Conroe Airport Relocated	N30	21	W95	[illegible]				12970	Houston	N29	59	W95	22	33
39	Orange	N										C9	West Orange	N30	5	W93	46				12924	Port Arthur	N29	57	W94	1	7
40	Tarrant	N	53907	Arlington Municipal Airport (GKY)	N32	40	W97	6	192.3			C61	Arlington Municipal Airport	N32	39	W97	5		111	University Hall (UT Arlington)	03931	Fort Worth	N32	50	W97	3	164
40	Tarrant	N	03927	Dallas - Fort Worth International Airpor (DFW)	N32	54	W97	1	170.7			C70	Grapevine Fairway	N32	58	W97	4				03932	Fort Worth	N32	50	W97	3	164
40	Tarrant	N	53909	Fort Worth Alliance Airport (AFW)	N32	58	W97	19	208.3			C13	Fort Worth Northwest	N32	48	W97	21				03933	Fort Worth	N32	50	W97	3	164
40	Tarrant	N	13961	Fort Worth Meacham (FTW)	N32	49	W97	22	209.4			C17	Keller (Fort Worth)	N32	55	W97	17				03934	Fort Worth	N32	50	W97	3	164
40	Tarrant	N										C75	Eagle Mountain Lake (Fort Worth)	N32	59	W97	[illegible]				03935	Fort Worth	N32	50	W97	3	164
41	Waller	N																			12971	Houston	N29	59	W95	22	33

Note:

	County No.	The affected and non attainment county numbers are listed orderly using table 19, p. 101, of the TERP Technical Report 2003. The other county numbers are listed alphabetically
NOAA	WBAN No.	Station's Weather Bureau Army Navy number
TMY2	WBAN No.	Station's Weather Bureau Army Navy number
NREL	Station No.	The station numbers are listed alphabetically
TCEQ	CAMS No.	The numbers are from TECQ
ESL	Site No.	ESL's site numbers
	Y in black:	The whole year's data is available
	Y in red:	The data is available for partial year

Table 49: Availability of Weather Data by County (NOAA, NREL, TCEQ, ESL).

2.5.1 1999 Hourly Weather data

In order to perform the DOE-2 simulations for the 1999 Ozone Episode Period (OEP), hourly weather files were assembled for each of the groups of counties. This resulted in (9) hourly 1999 weather files, including:

- Tyler/Longview Area (NOAA GGG data, NREL Overton data)
- Corpus Christi Area (NOAA CRP data, NREL Corpus data)
- Dallas Ft. Worth Area (NOAA DFW data, NREL Overton data)
- Victoria area (NOAA VCT data, TCEQ Camp Bullis data)
- Beaumont – Pt.Arthur area (NOAA Port Arthur A.P. data, TCEQ Galveston A.P. data)
- San Antonio area (NOAA SAT data, TCEQ Camp Bullis data)
- Houston/Galveston area (NOAA IAH data, NREL Clear Lake data)
- Austin area (NOAA ATT site, NREL Austin data)
- El Paso area (NOAA ELP data, UTEP TCEQ data)

Statistics about the data for each site is presented in Table 50 through Table 58. Time series plots of the hourly data are presented in Figure 72 through Figure 80. In Table 50 and Figure 72, data are shown for the Tyler/Longview Area (i.e., NOAA GGG data, NREL Overton data), including the statistics about the missing data, and time series plots that show the missing data. These plots are then followed by plots for the same period that show the data after the data filling routines had been applied to the data for temperature and humidity data. For the remaining sites, all data shown represent filled datasets.

2.5.1.1 Tyler/Longview Area (NOAA GGG site)

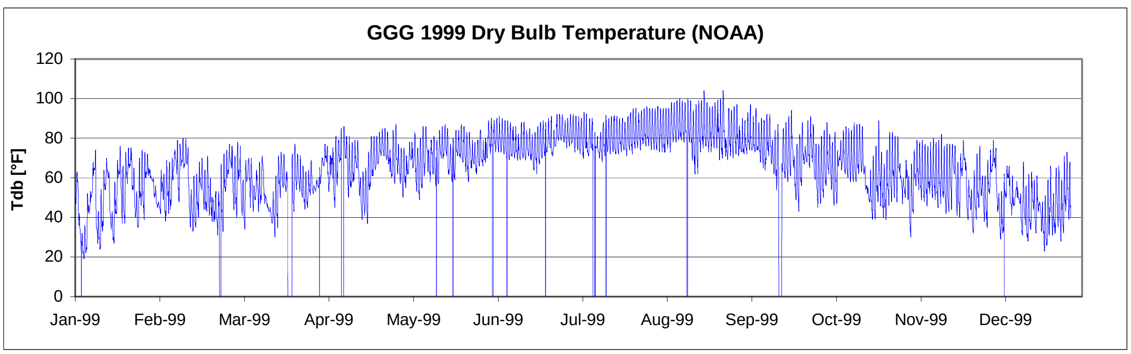
1. Weather data source
   - Weather Station: Longview E Tx Rgnl Airport (GGG), NOAA
   - Solar Station: Overton, NREL

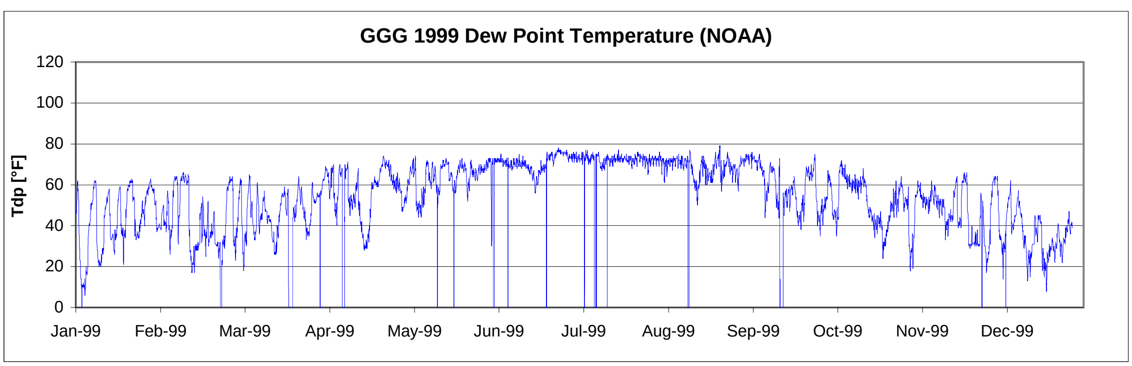
2. Summary of missing data

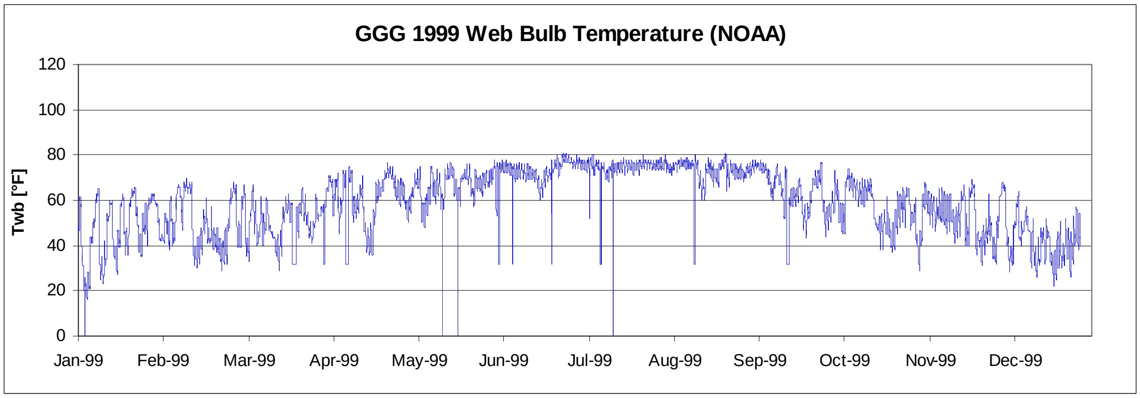
Station Name	Data Source	Data Type	# of Hours Missing Data (less than 6 hours)	# of Hours Missing Data (more than 6 hours)
Overton	NREL	Global	0	0
		Direct normal	0	0
		Diffuse	0	0
GGG	NOAA	Dry bulb temperature	18	117
		Wet bulb temperature	4	0
		Dew point temperature	29	0
		Wind speed		
		Total precipitation		

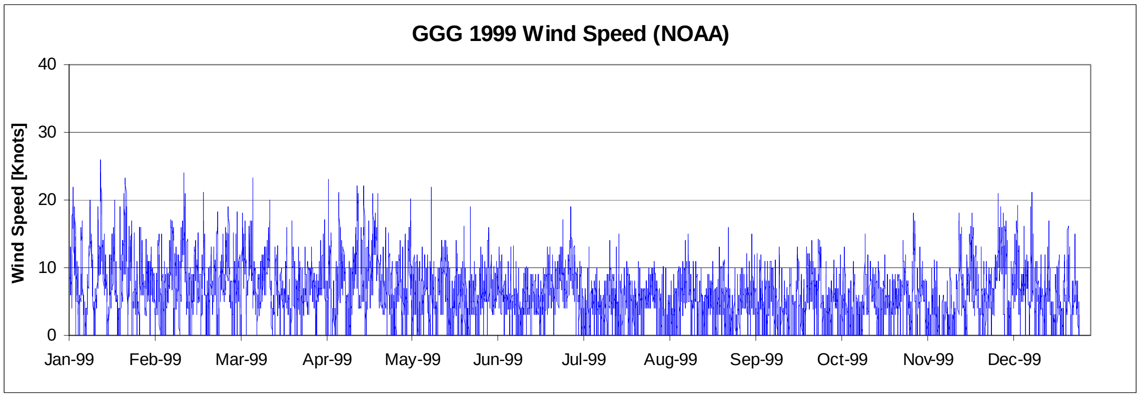
Table 50: Summary of Missing Data (Tyler/Longview Area - NOAA GGG site).

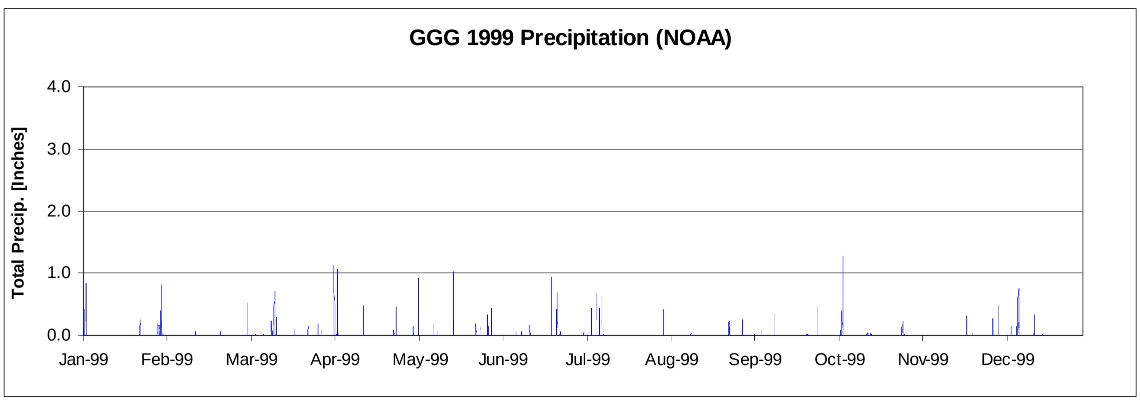
3. Time series plots for original hourly weather data

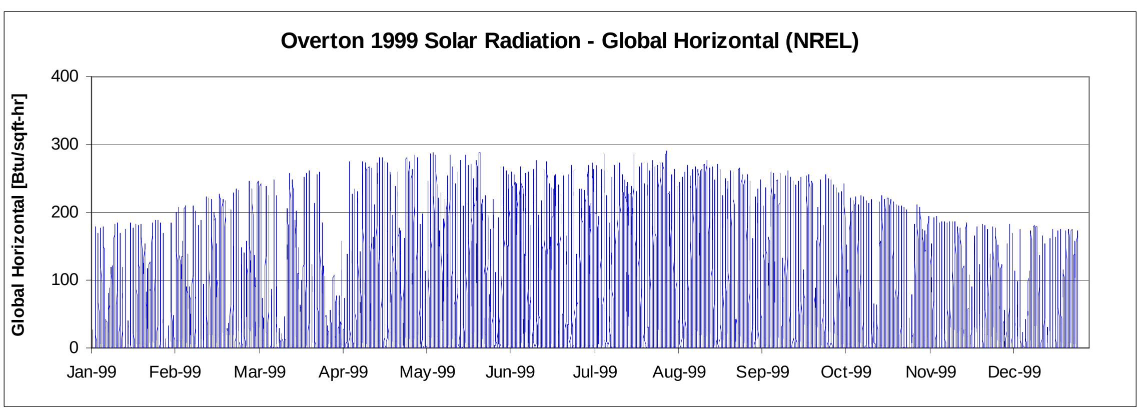


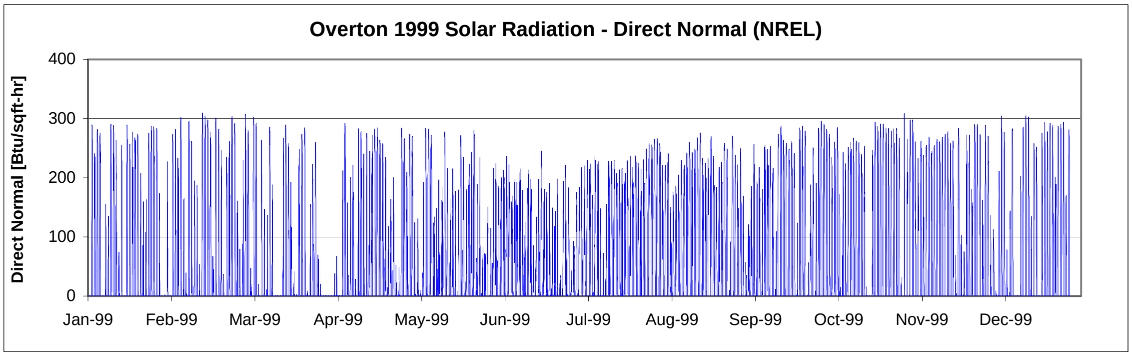



GGG 1999 Web Bulb Temperature (NOAA)
Twb [°F]
120
100
80
60
40
20
0
Jan-99 Feb-99 Mar-99 Apr-99 May-99 Jun-99 Jul-99 Aug-99 Sep-99 Oct-99 Nov-99 Dec-99

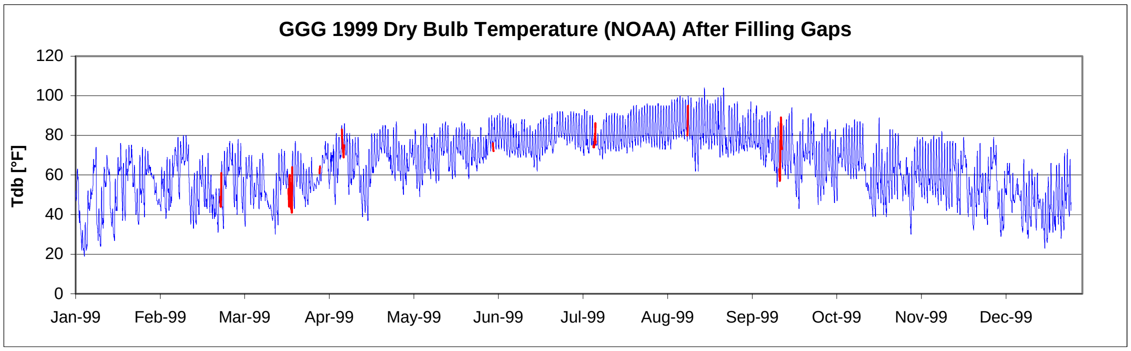

GGG 1999 Wind Speed (NOAA)
Wind Speed [Knots]
40
30
20
10
0
Jan-99 Feb-99 Mar-99 Apr-99 May-99 Jun-99 Jul-99 Aug-99 Sep-99 Oct-99 Nov-99 Dec-99

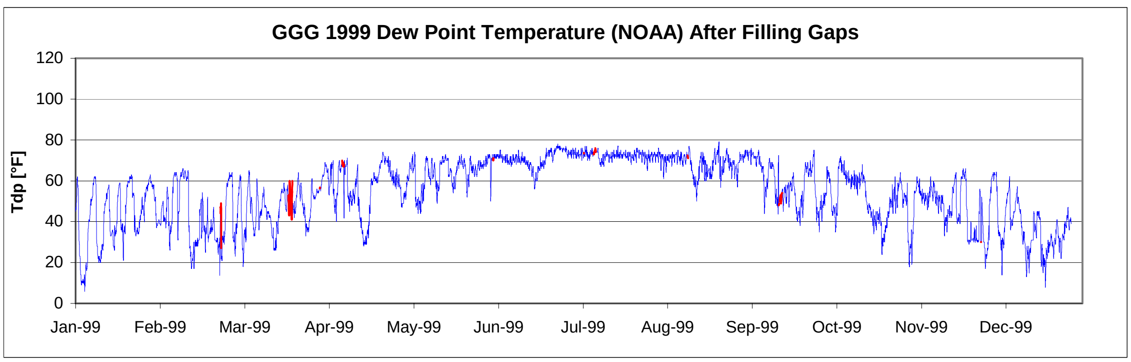

GGG 1999 Precipitation (NOAA)
Total Precip. [Inches]
4.0
3.0
2.0
1.0
0.0
Jan-99 Feb-99 Mar-99 Apr-99 May-99 Jun-99 Jul-99 Aug-99 Sep-99 Oct-99 Nov-99 Dec-99


Overton 1999 Solar Radiation - Global Horizontal (NREL)
Global Horizontal [Btu/sqft-hr]
400
300
200
100
0
Jan-99 Feb-99 Mar-99 Apr-99 May-99 Jun-99 Jul-99 Aug-99 Sep-99 Oct-99 Nov-99 Dec-99



4. Time series plots for hourly weather data after filling gaps





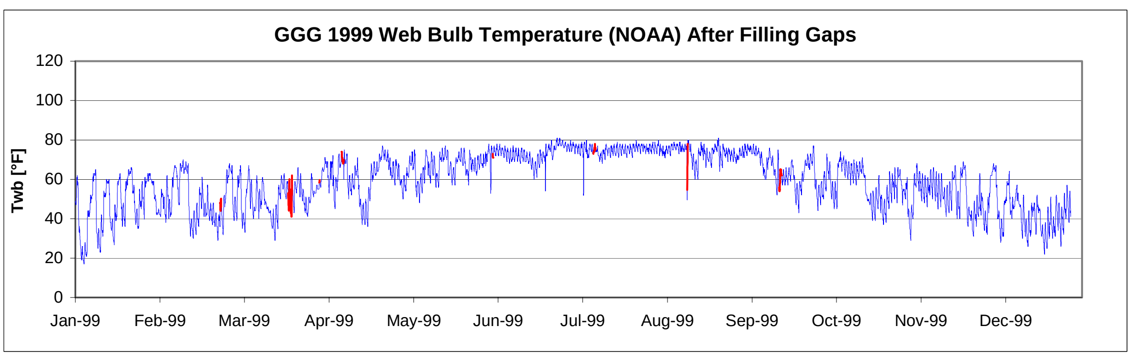


Figure 72: 1999 Hourly Weather Data (Tyler/Longview Area - NOAA GGG site).

2.5.1.2 Corpus Christi Area (NOAA CRP site)

1. Weather data source

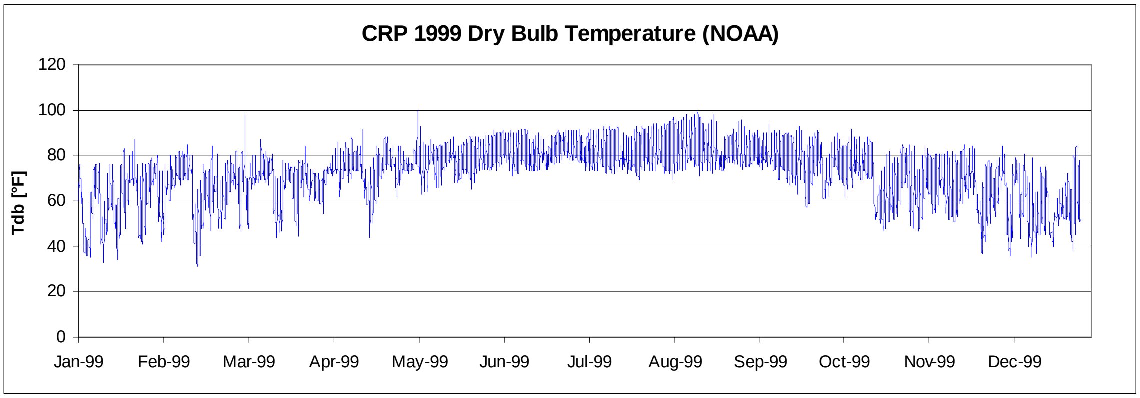
- Weather Station: Corpus Christi International Airport (CRP), NOAA
- Solar Station: Corpus Christi, NREL

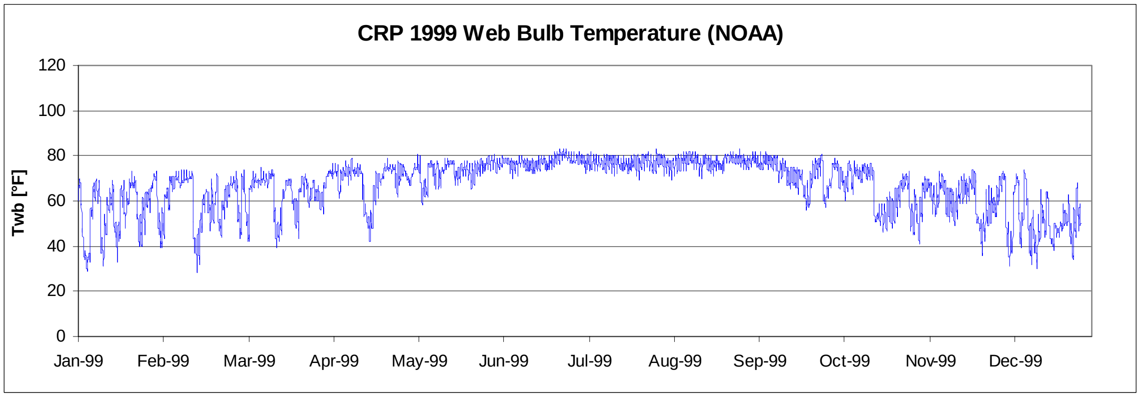
2. Summary of missing data

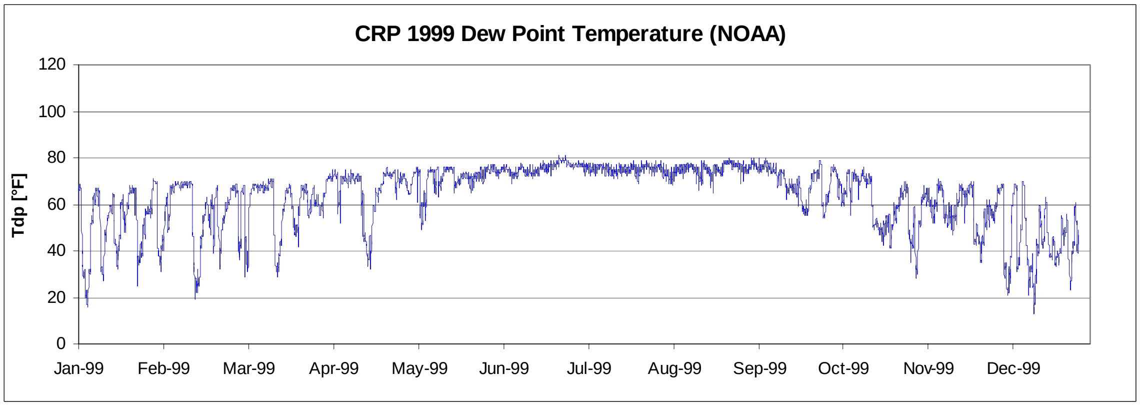
Station Name	Data Source	Data Type	# of Hours Missing Data (less than 6 hours)	# of Hours Missing Data (more than 6 hours)
Corpus Christi	NREL	Global	0	0
		Direct normal	0	0
		Diffuse	0	0
CRP	NOAA	Dry bulb temperature	3	0
		Wet bulb temperature	3	0
		Dew point temperature	3	0
		Wind speed		
		total Precip		

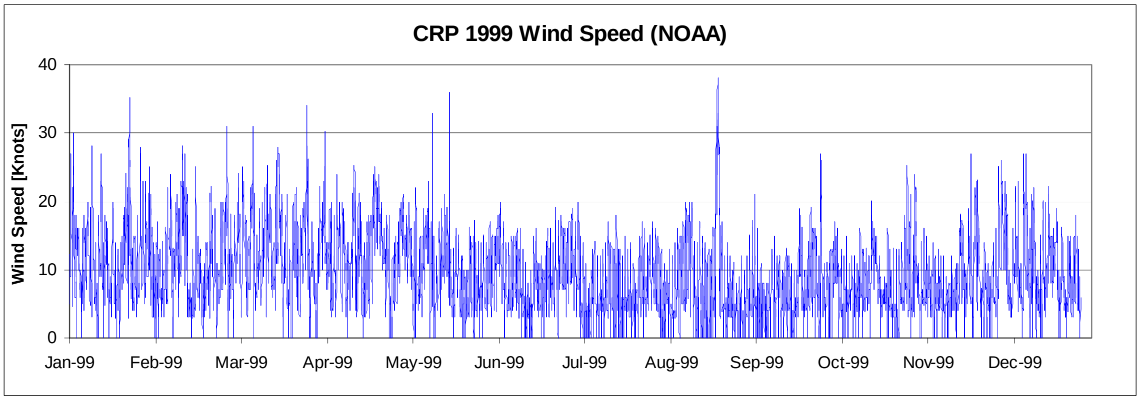
Table 51: Summary of Missing Data (Corpus Christi Area - NOAA CRP site).

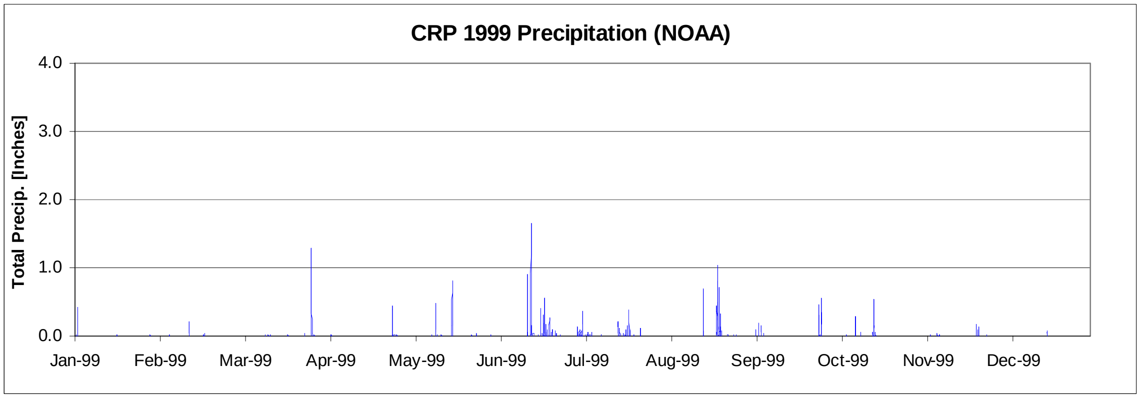
3. Time series plots for hourly weather data after filling gaps

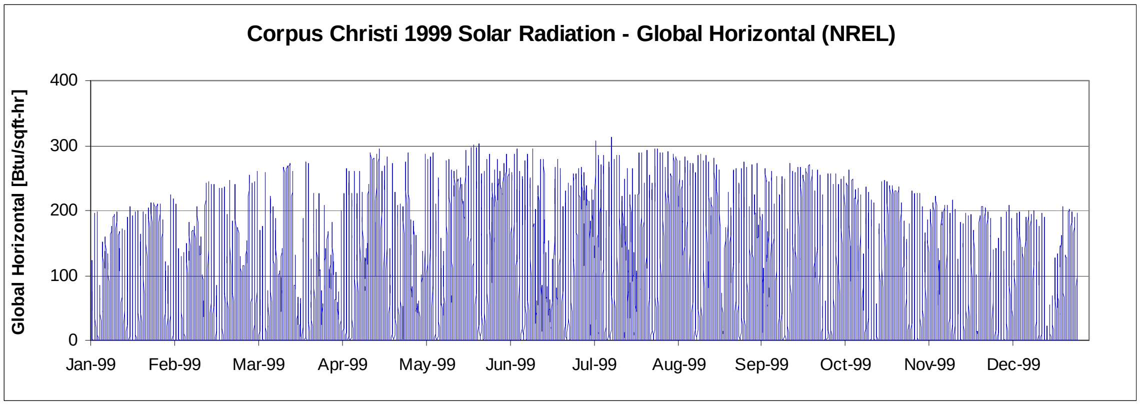





CRP 1999 Dew Point Temperature (NOAA)
Tdp [°F]
120
100
80
60
40
20
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


CRP 1999 Wind Speed (NOAA)
Wind Speed [Knots]
40
30
20
10
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


CRP 1999 Precipitation (NOAA)
Total Precip. [Inches]
4.0
3.0
2.0
1.0
0.0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99



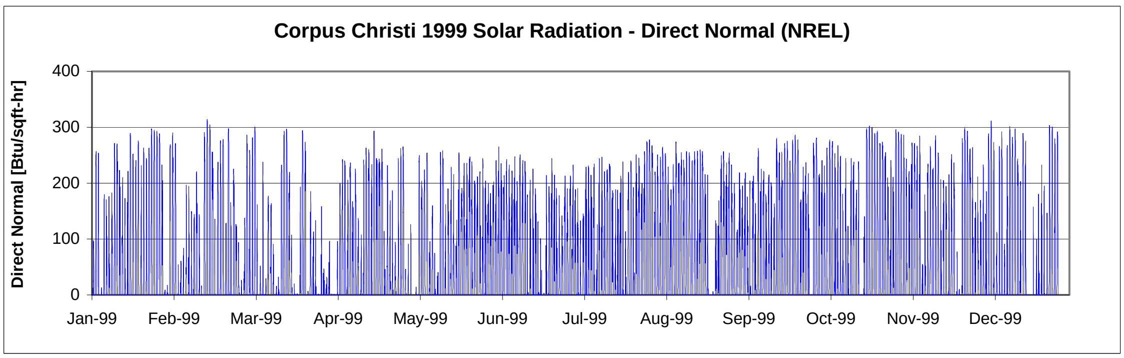


Figure 73: 1999 Hourly Weather Data (Corpus Christi Area - NOAA CRP site).

2.5.1.3 Dallas-Ft. Worth Area (NOAA DFW site)

1. Weather data source

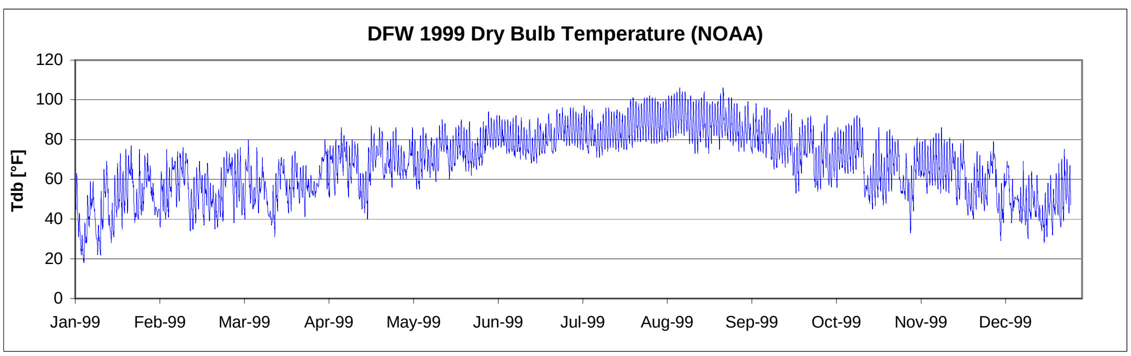
- Weather Station: Dallas-Ft. Worth International Airport (DFW), NOAA
- Solar Station: NREL-Overton, NREL

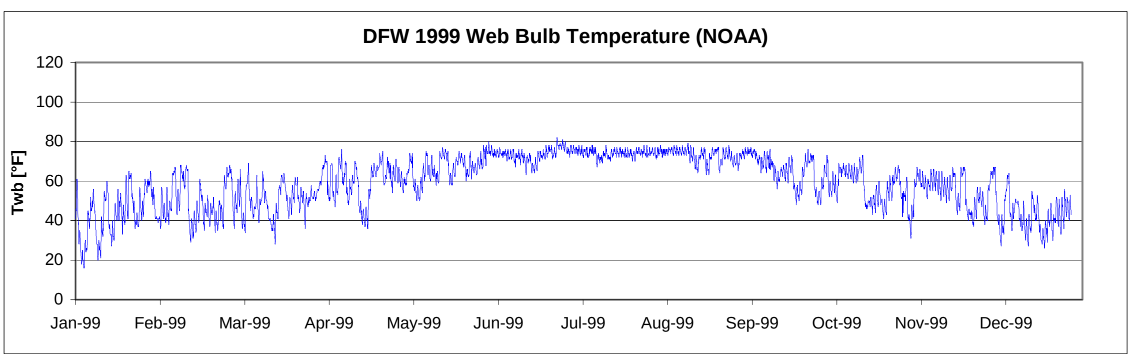
2. Summary of missing data

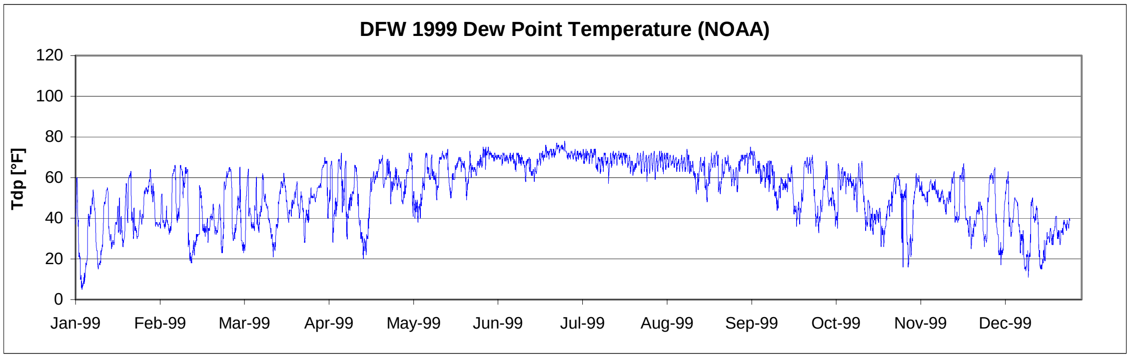
Station Name	Data Source	Data Type	# of Hours Missing Data (less than 6 hours)	# of Hours Missing Data (more than 6 hours)
Overton	NREL	Global	0	0
		Direct normal	0	0
		Diffuse	0	0
DFW	NOAA	Dry bulb temperature	0	0
		Wet bulb temperature	0	0
		Dew point temperature	0	0
		Wind speed	0	0
		Total precipitation	0	0

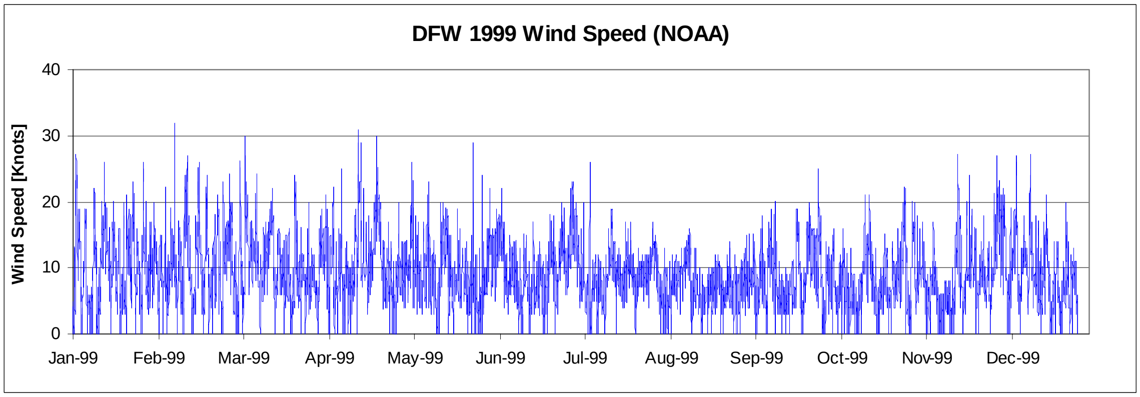
Table 52: Summary of Missing Data (Dallas-Ft. Worth Area - NOAA DFW site).

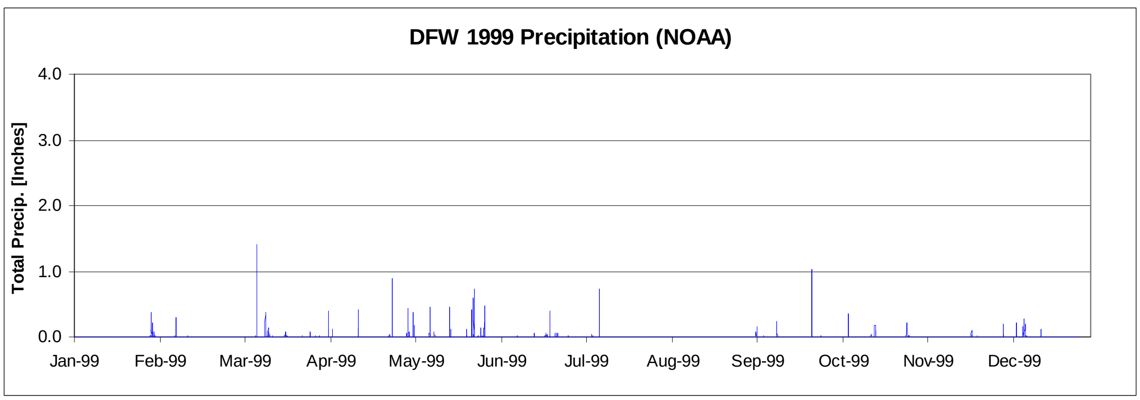
3. Time series plots for hourly weather data after filling gaps

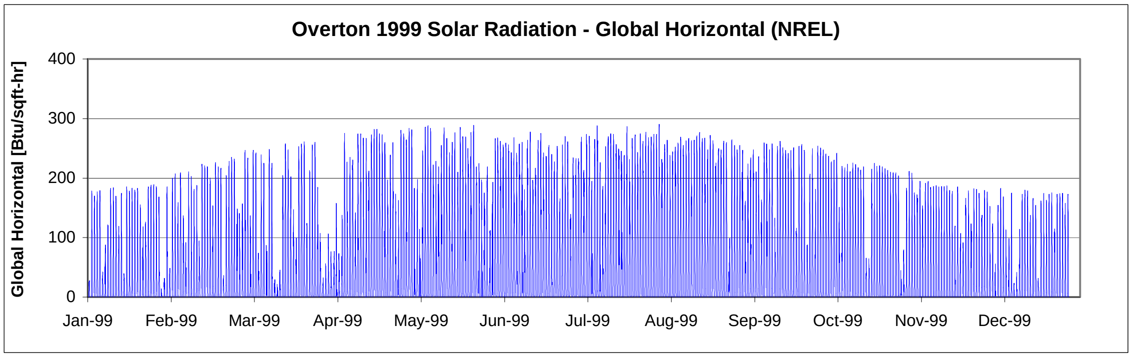





DFW 1999 Dew Point Temperature (NOAA)
Tdp [°F]
120
100
80
60
40
20
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


DFW 1999 Wind Speed (NOAA)
Wind Speed [Knots]
40
30
20
10
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


DFW 1999 Precipitation (NOAA)
Total Precip. [Inches]
4.0
3.0
2.0
1.0
0.0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99



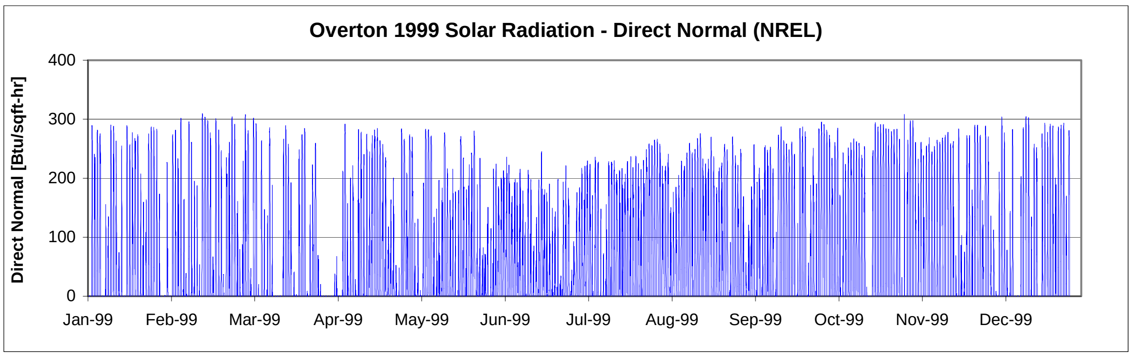


Figure 74: 1999 Hourly Weather Data (Dallas-Ft. Worth Area -NOAA DFW site).

2.5.1.4 Victoria Area (NOAA VCT site)

1. Weather data source

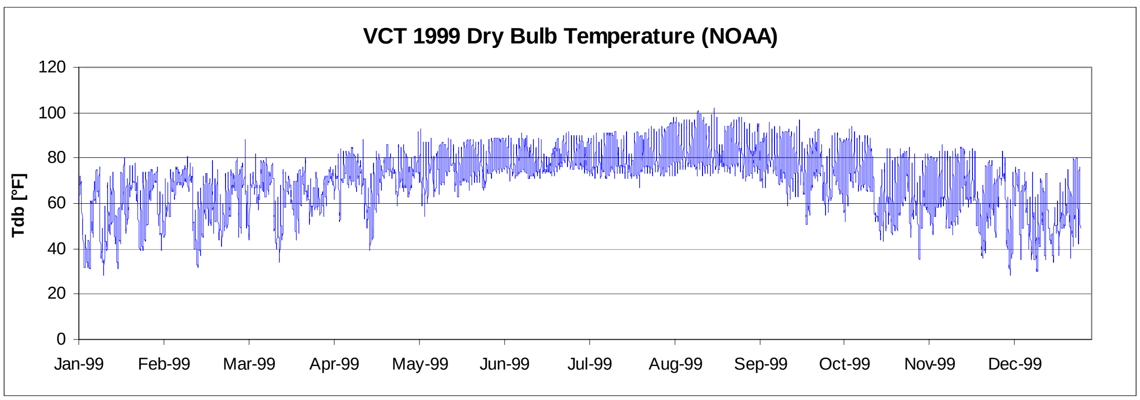
- Weather Station: Victoria Regional Airport (VCT), NOAA
- Solar Station: C58-Camp Bullis, TCEQ

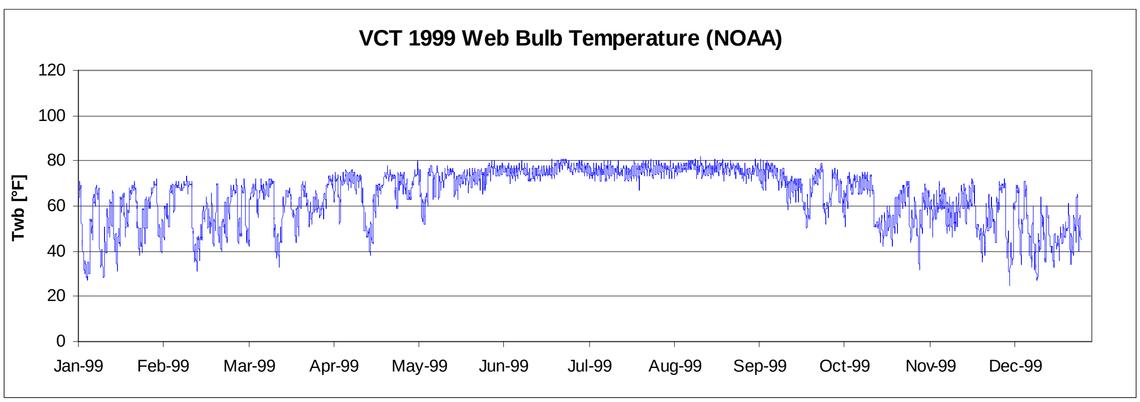
2. Summary of missing data

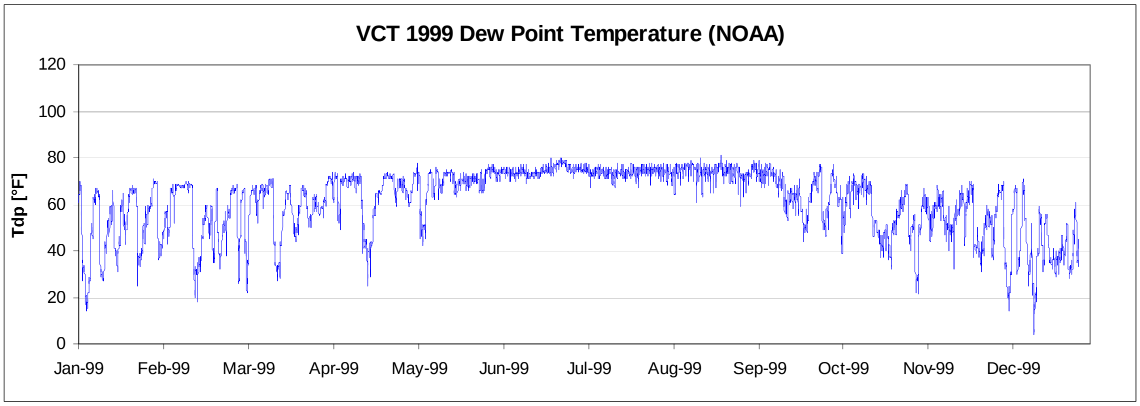
Station Name	Data Source	Data Type	# of Hours Missing Data (less than 6 hours)	# of Hours Missing Data (more than 6 hours)
C58-Camp Bullis	TCEQ	Global	22	10
VCT	NOAA	Dry bulb temperature	6	0
		Wet bulb temperature	2	0
		Dew point temperature	6	0
		Wind speed		
		total Precip		

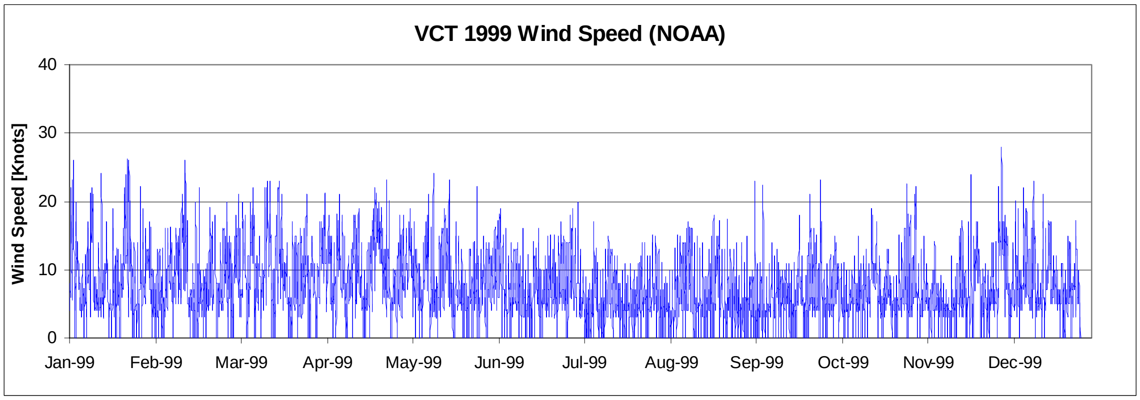
Table 53: Summary of Missing Data (Victoria Area -NOAA VCT site).

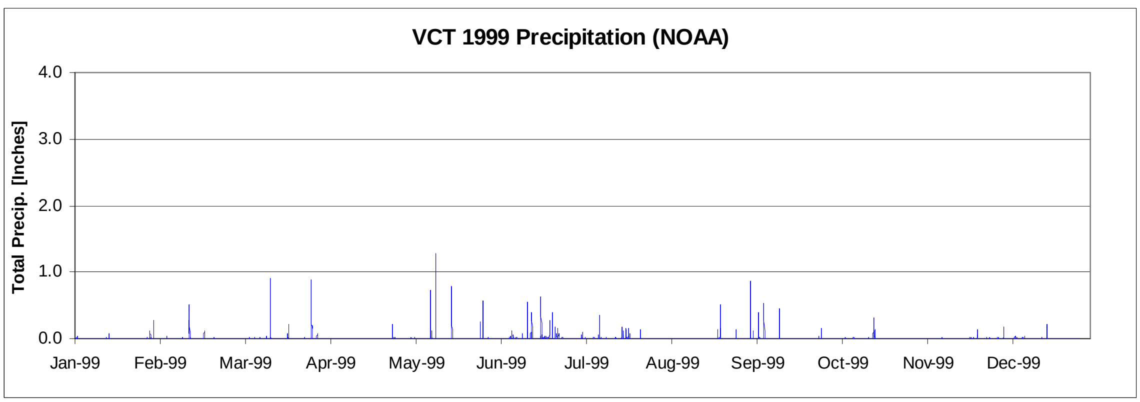
3. Time series plots for hourly weather data after filling gaps






VCT 1999 Dew Point Temperature (NOAA)
Tdp [°F]
120
100
80
60
40
20
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


VCT 1999 Wind Speed (NOAA)
Wind Speed [Knots]
40
30
20
10
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


VCT 1999 Precipitation (NOAA)
Total Precip. [Inches]
4.0
3.0
2.0
1.0
0.0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99

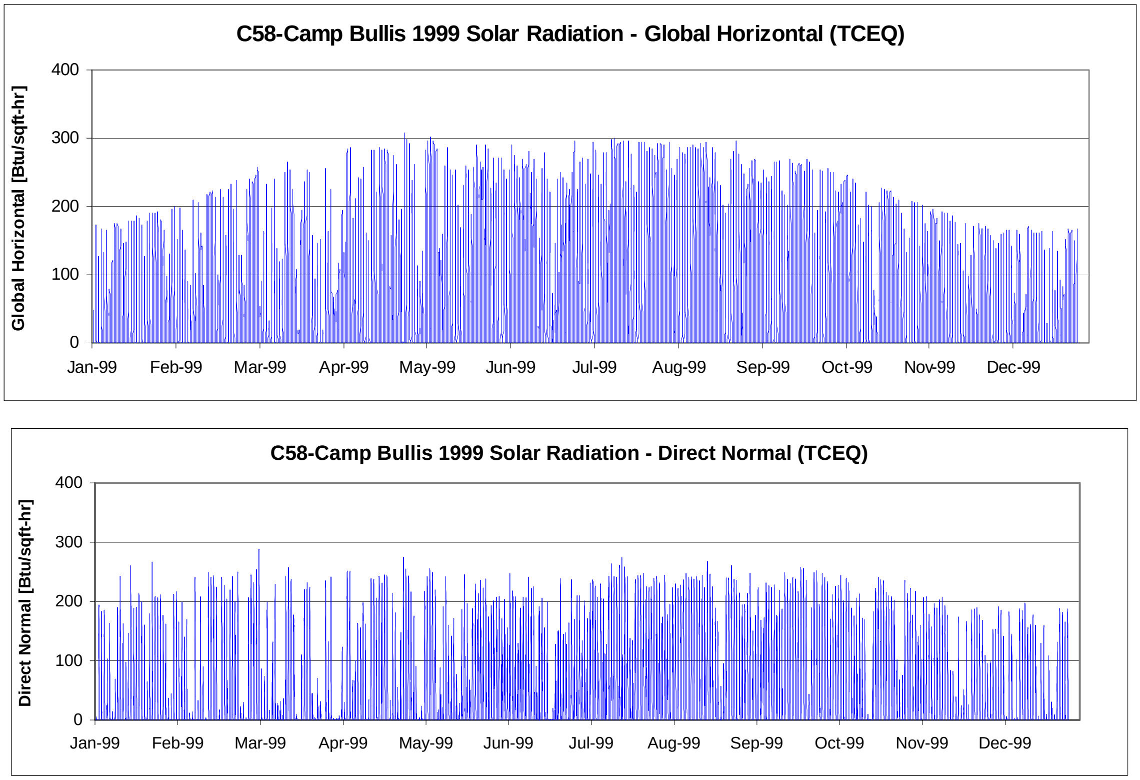


Figure 75: 1999 Hourly Weather Data (Victoria Area -NOAA VCT site).

2.5.1.5 Beaumont - Pt. Arthur Area (NOAA BPT site)

1. Weather data source

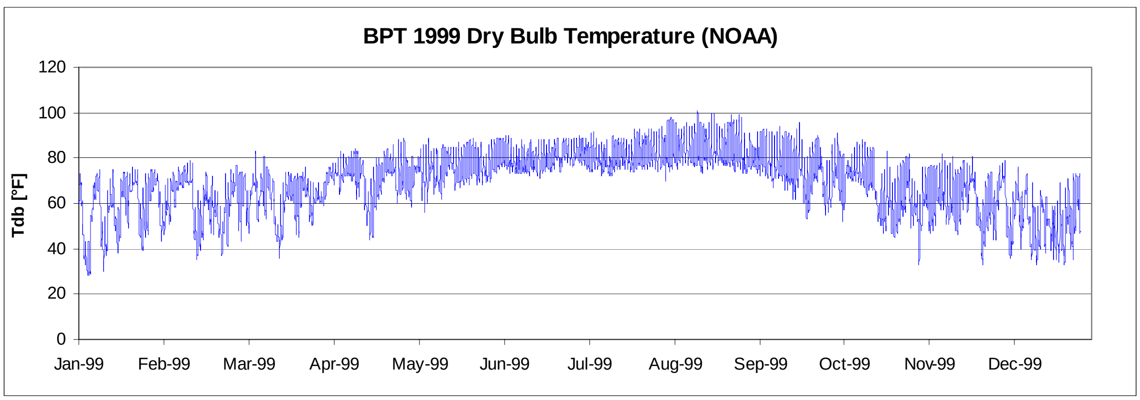
- Weather Station: Port Arthur Se Tx Rgnl Airport (BPT), NOAA
- Solar Station: C34-Galveston Airport, TCEQ

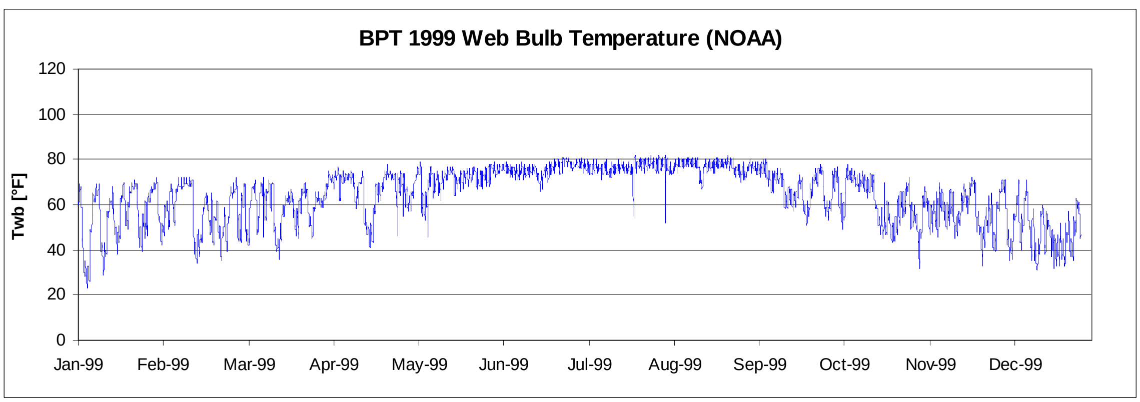
2. Summary of missing data

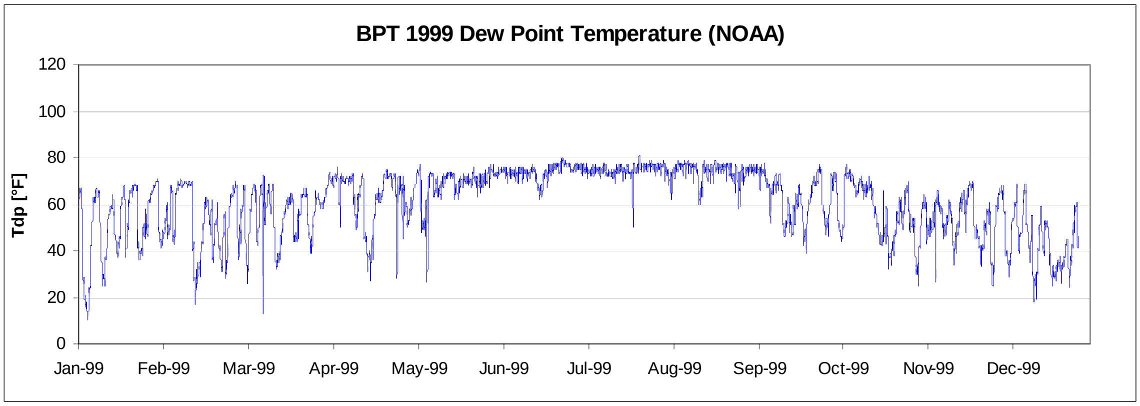
Station Name	Data Source	Data Type	# of Hours Missing Data (less than 6 hours)	# of Hours Missing Data (more than 6 hours)
C34-Galveston Airport	TCEQ	Global	9	1063
BPT	NOAA	Dry bulb temperature	6	0
		Wet bulb temperature	2	0
		Dew point temperature	20	7
		Wind speed		
		Total precipitation		

Table 54: Summary of Missing Data (Beaumont/Port Arthur Area - NOAA BPT site).

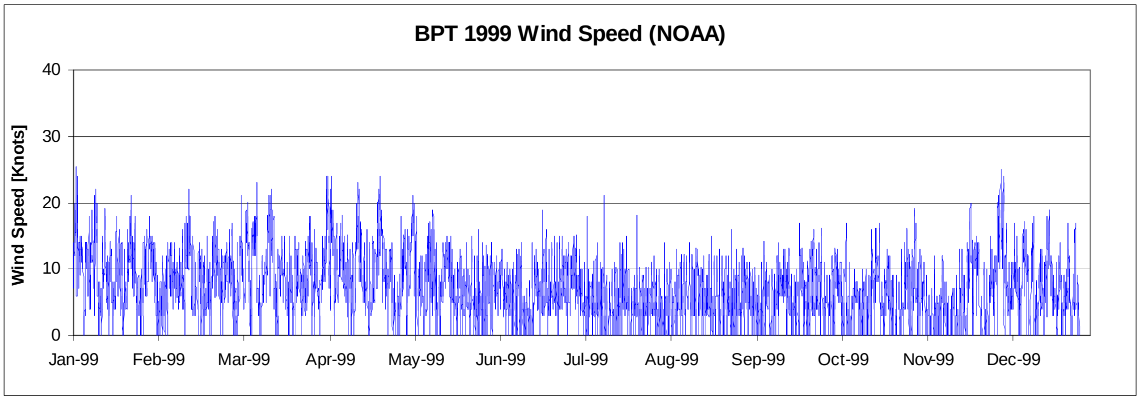
3. Time series plots for hourly weather data after filling gaps



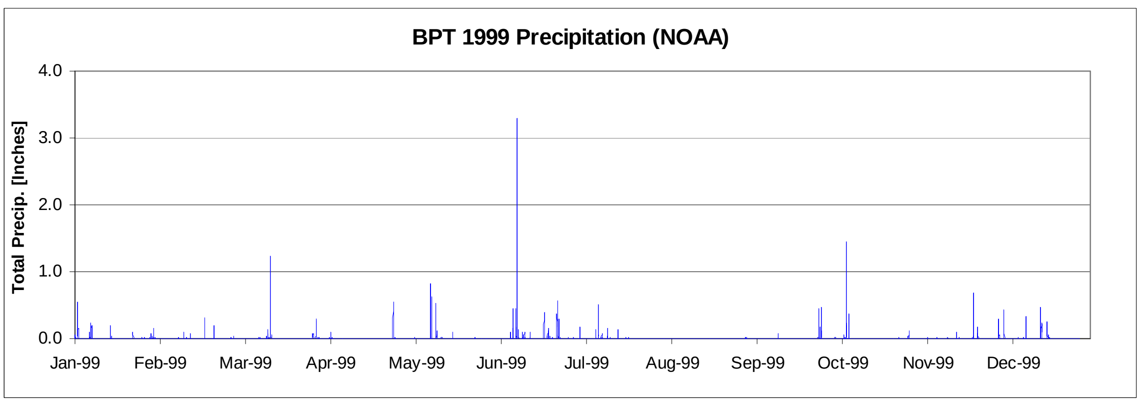




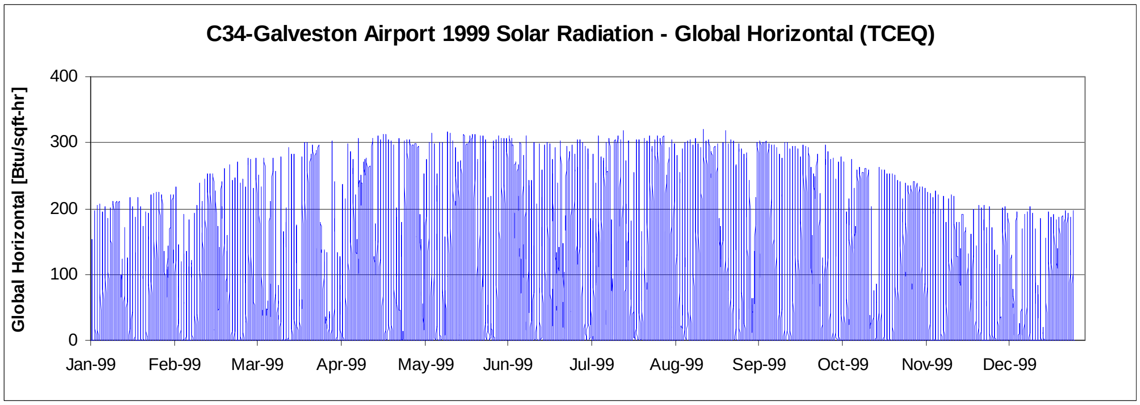
BPT 1999 Dew Point Temperature (NOAA)
Tdp [°F]
120
100
80
60
40
20
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99



BPT 1999 Wind Speed (NOAA)
Wind Speed [Knots]
40
30
20
10
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99



BPT 1999 Precipitation (NOAA)
Total Precip. [Inches]
4.0
3.0
2.0
1.0
0.0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99



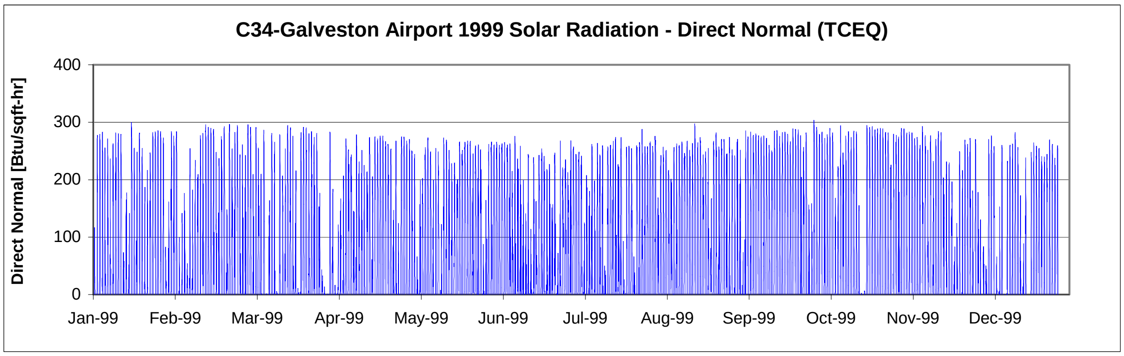


Figure 76: 1999 Hourly Weather Data (Beaumont/Port Arthur Area - NOAA BPT site).

2.5.1.6 San Antonio Area (NOAA SAT site)

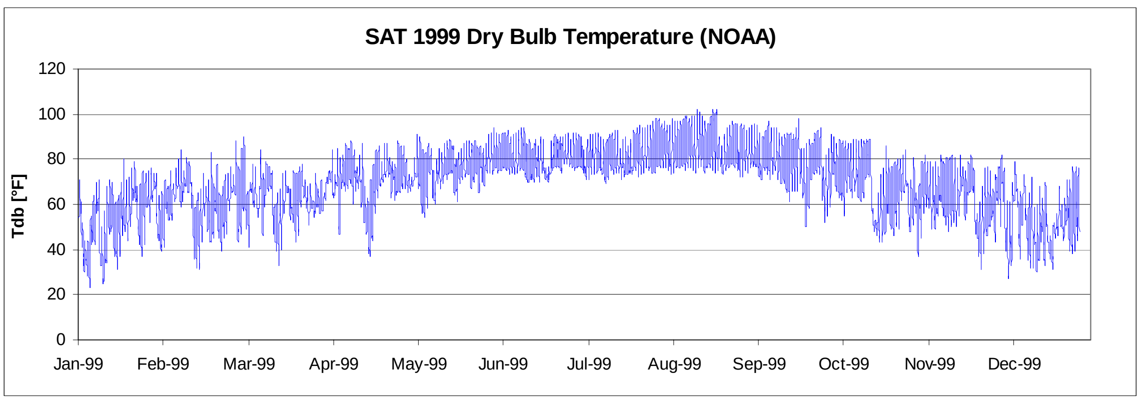
1. Weather data source
- Weather Station: San Antonio International Airport (SAT), NOAA
- Solar Station: C-58-Camp Bullis, TCEQ

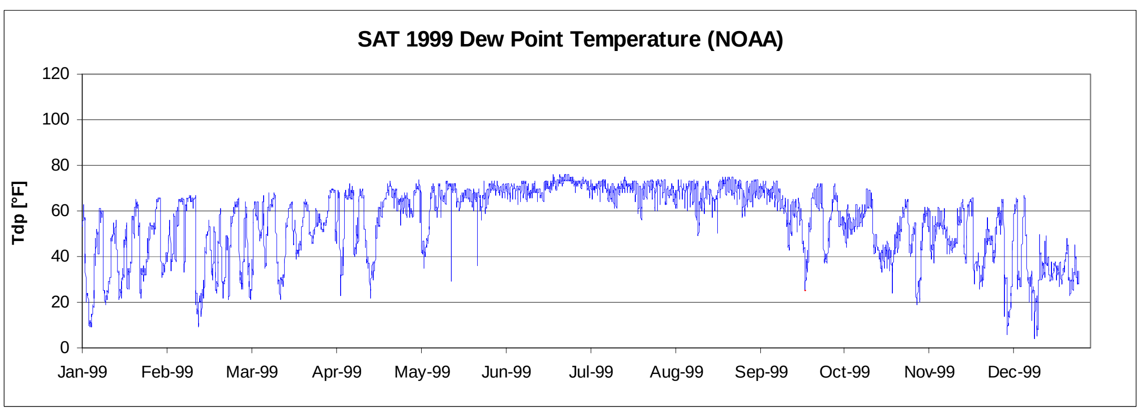
2. Summary of missing data

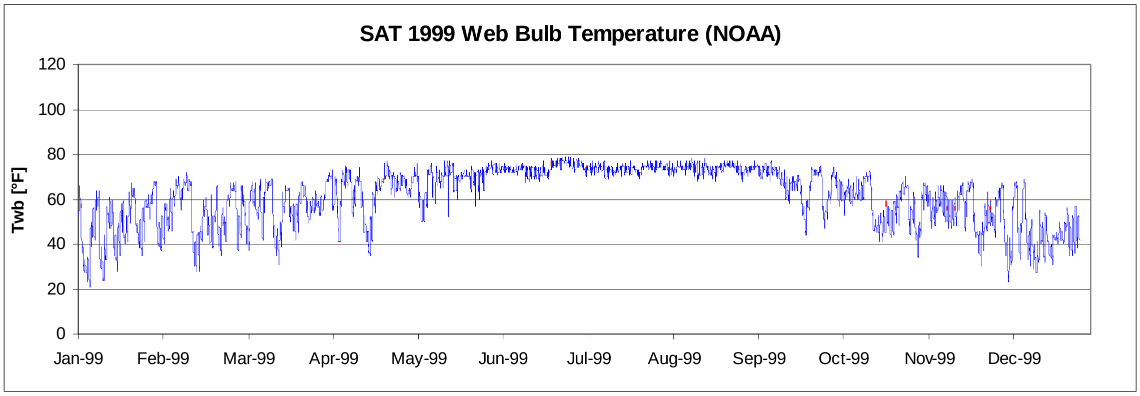
Station Name	Data Source	Data Type	# of Hours Missing Data (less than 6 hours)	# of Hours Missing Data (more than 6 hours)
C-58-Camp Bullis	TCEQ	Global	0	0
SAT	NOAA	Dry bulb temperature	1	0
		Wet bulb temperature	1	0
		Dew point temperature	1	0
		Wind speed	0	0
		Total precipitation	0	0

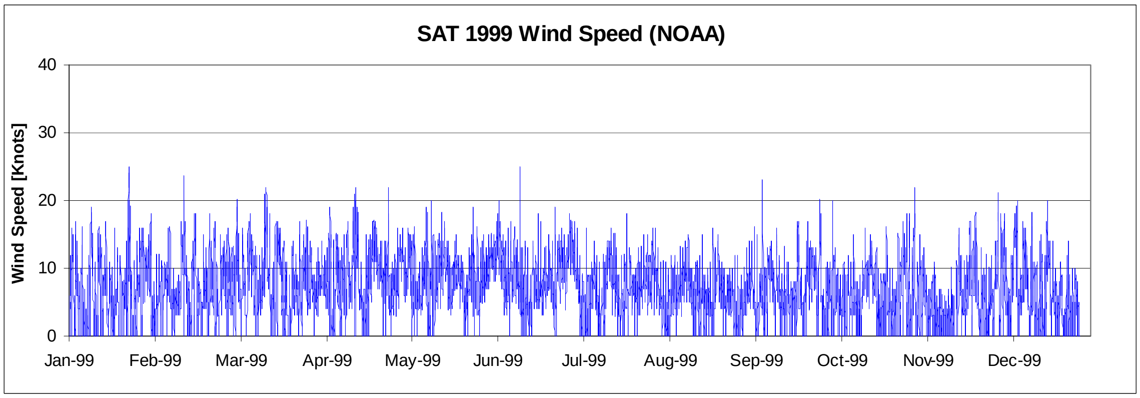
Table 55: Summary of Missing Data (San Antonio Area -NOAA SAT site).

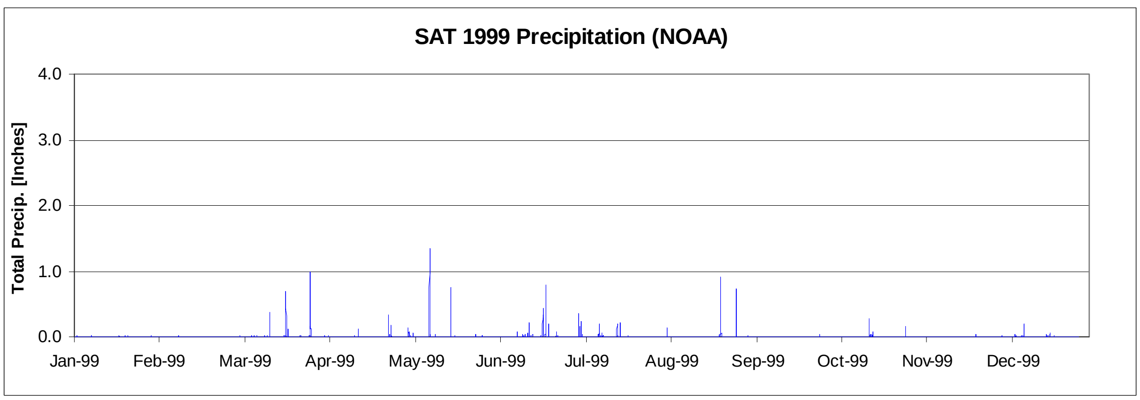
3. Time series plots for hourly weather data after filling gaps

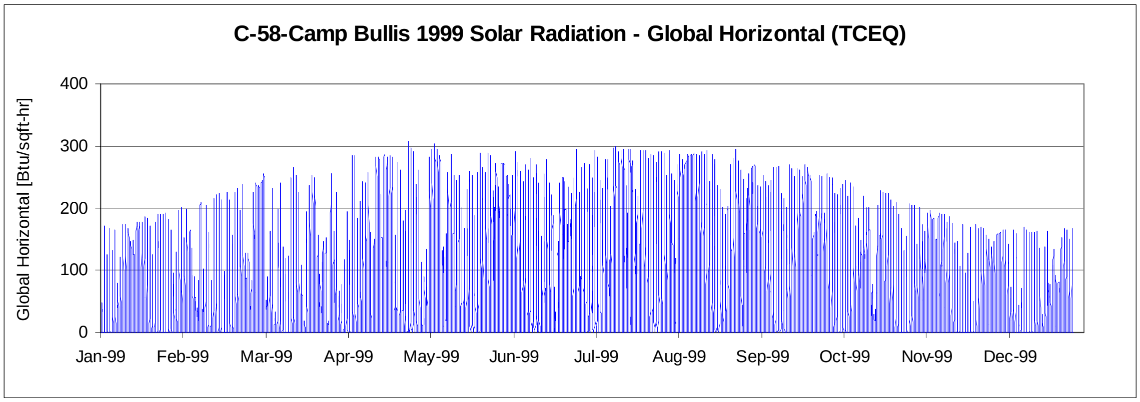





SAT 1999 Web Bulb Temperature (NOAA)
Twb [°F]
120
100
80
60
40
20
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


SAT 1999 Wind Speed (NOAA)
Wind Speed [Knots]
40
30
20
10
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


SAT 1999 Precipitation (NOAA)
Total Precip. [Inches]
4.0
3.0
2.0
1.0
0.0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99



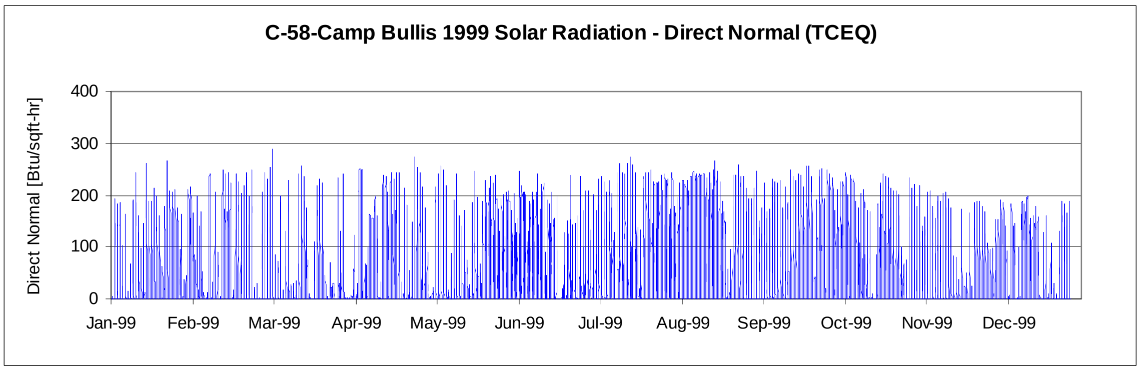


Figure 77: 1999 Hourly Weather Data (San Antonio Area -NOAA SAT site).

2.5.1.7 Houston/Galveston Area (NOAA IAH site)

1. Weather data source

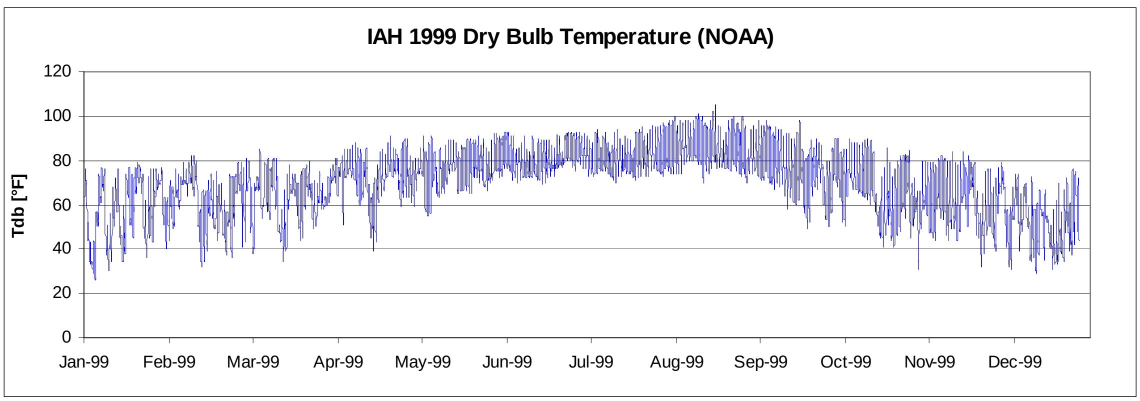
- Weather Station: Houston Bush Intercontinental (IAH), NOAA
- Solar Station: Clear Lake, NREL

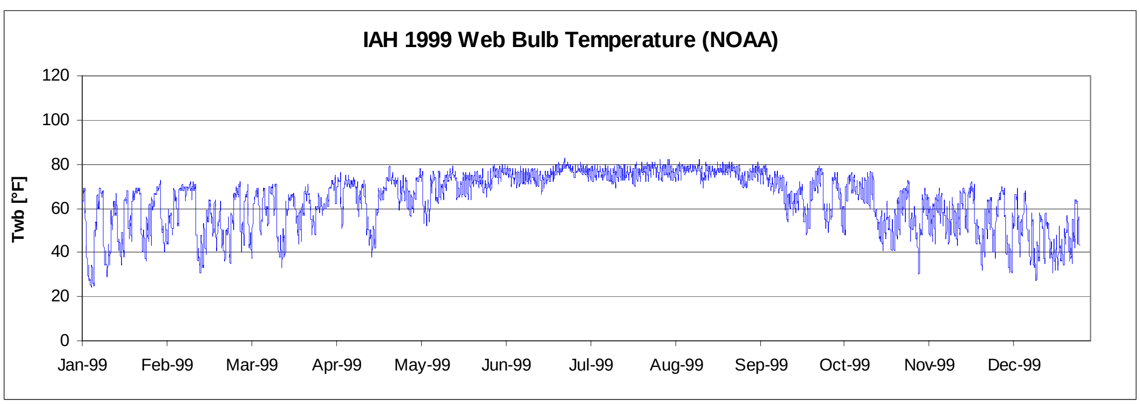
2. Summary of missing data

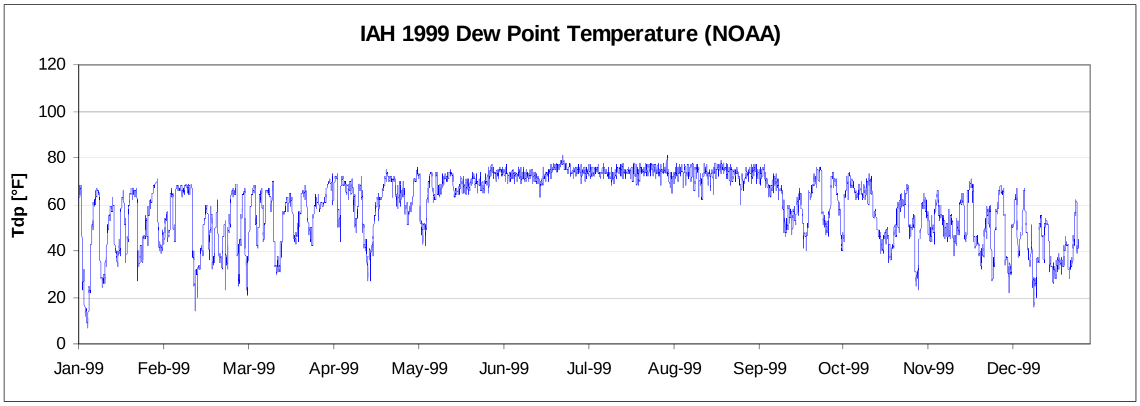
Station Name	Data Source	Data Type	# of Hours Missing Data (less than 6 hours)	# of Hours Missing Data (more than 6 hours)
Clear Lake	NREL	Global	0	0
		Direct normal	0	0
		Diffuse	0	0
IAH	NOAA	Dry bulb temperature	4	0
		Wet bulb temperature	2	0
		Dew point temperature	4	0
		Wind speed		
		Total precipitation		

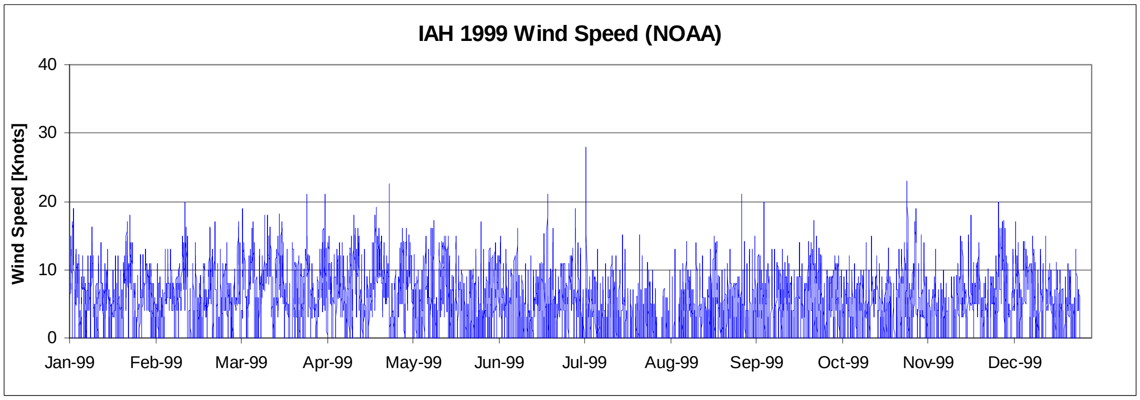
Table 56: Summary of Missing Data (Houston/Galveston Area - NOAA IAH site).

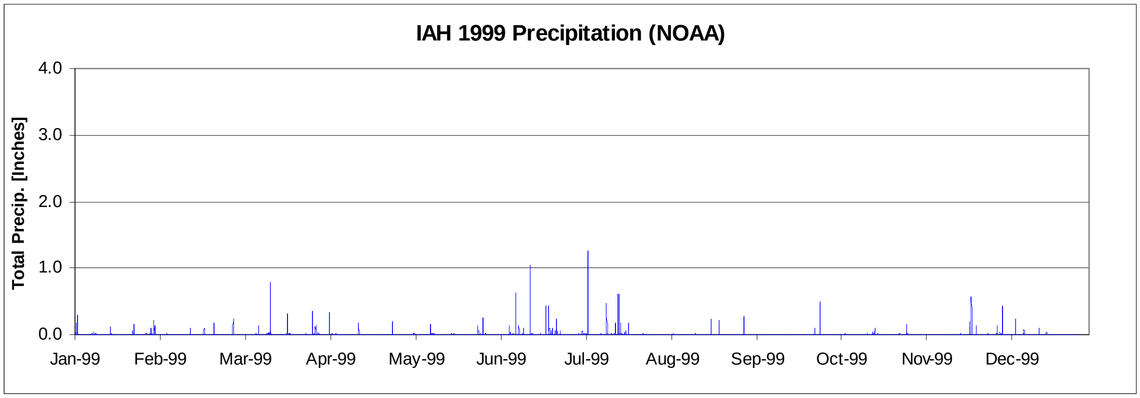
3. Time series plots for hourly weather data after filling gaps

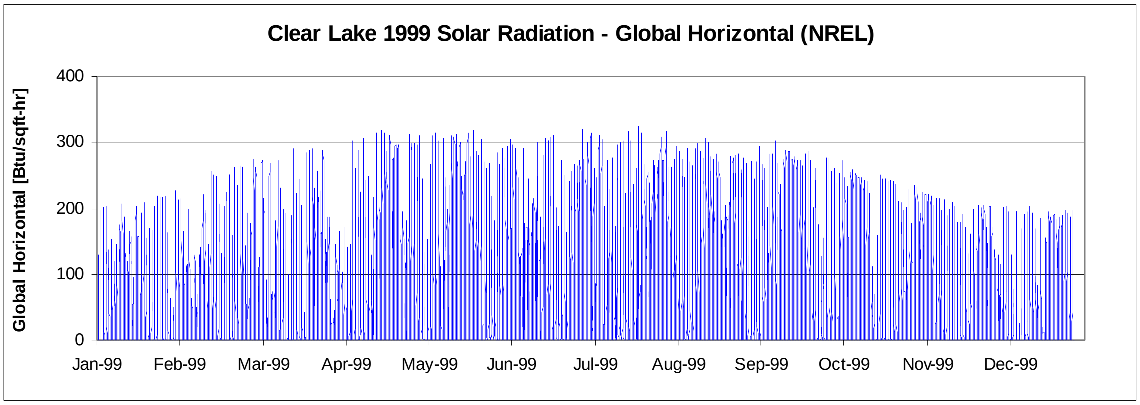





IAH 1999 Dew Point Temperature (NOAA)
Tdp [°F]
120
100
80
60
40
20
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


IAH 1999 Wind Speed (NOAA)
Wind Speed [Knots]
40
30
20
10
0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


IAH 1999 Precipitation (NOAA)
Total Precip. [Inches]
4.0
3.0
2.0
1.0
0.0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99



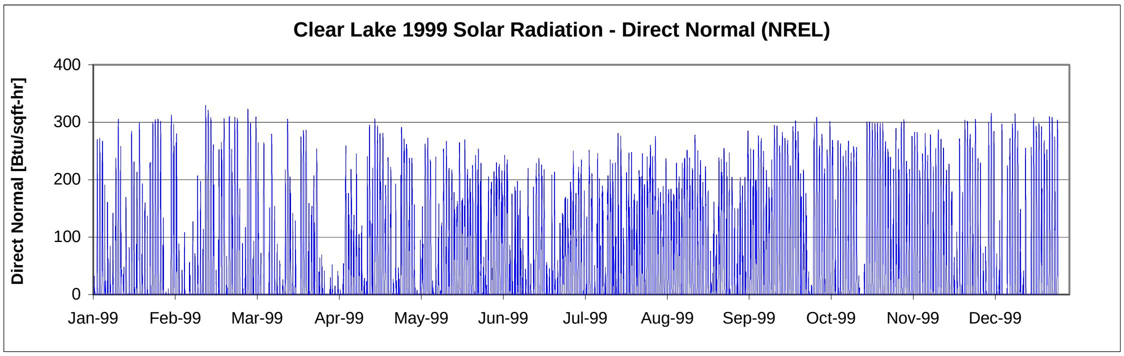


Figure 78: 1999 Hourly Weather Data (Houston/Galveston Area - NOAA IAH site).

2.5.1.8 Austin Area (NOAA ATT site)

1. Weather data source

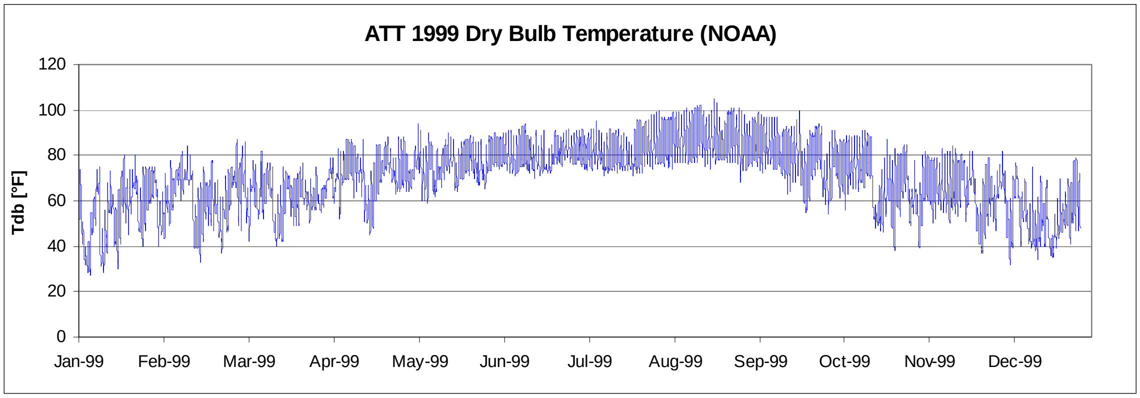
- Weather Station: Austin Camp Mabry (ATT), NOAA
- Solar Station: Austin, NREL

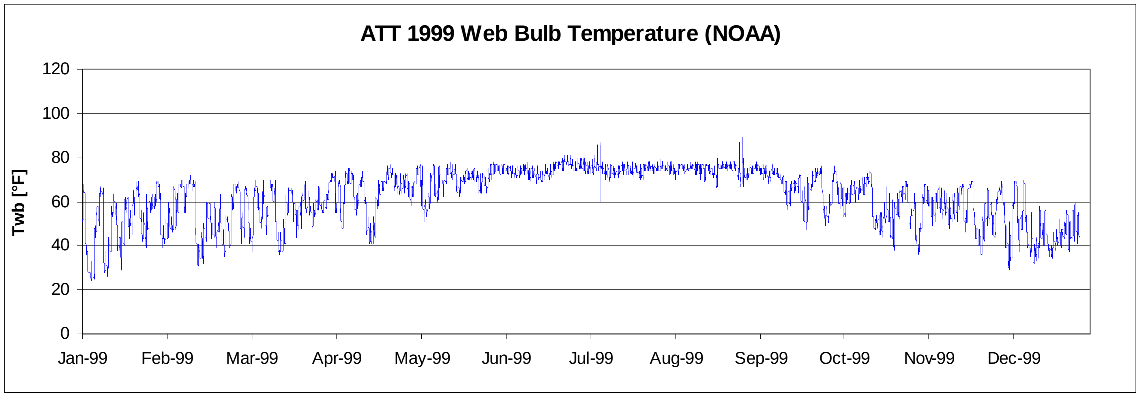
2. Summary of missing data

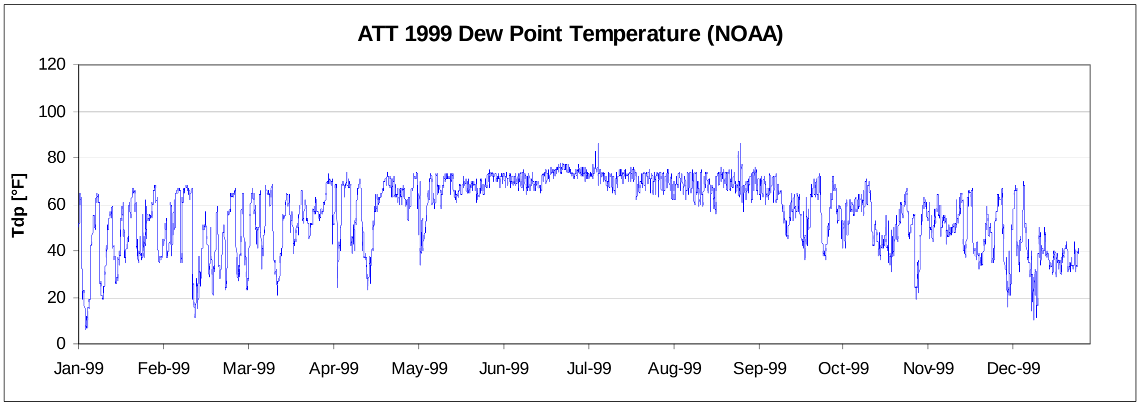
Station Name	Data Source	Data Type	# of Hours Missing Data (less than 6 hours)	# of Hours Missing Data (more than 6 hours)
Austin	NREL	Global	0	0
		Direct normal	0	0
		Diffuse	0	0
ATT	NOAA	Dry bulb temperature	19	116
		Wet bulb temperature	7	91
		Dew point temperature	21	116
		Wind speed		
		total Precip		

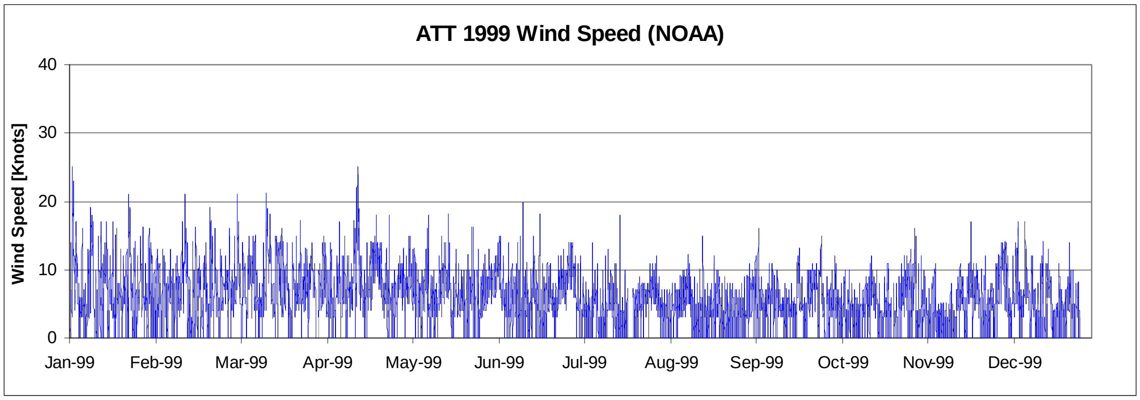
Table 57: Summary of Missing Data (Austin Area - NOAA ATT site).

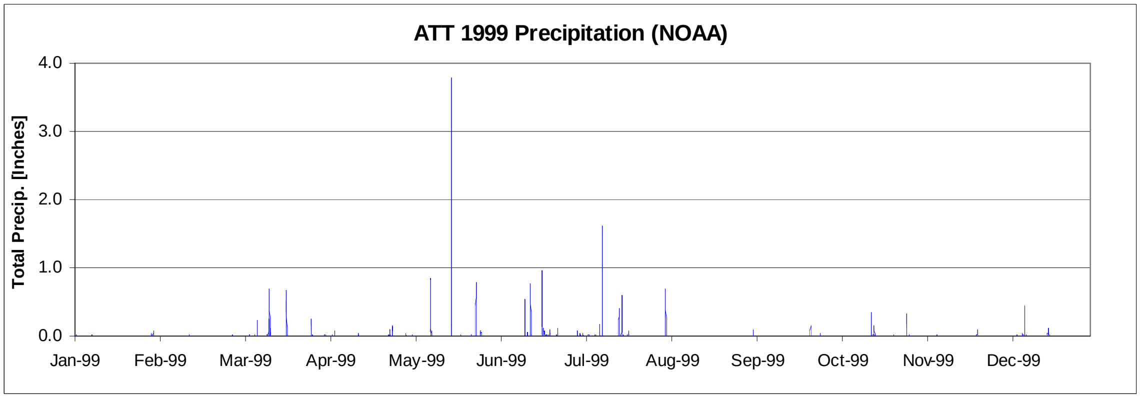
3. Time series plots for hourly weather data after filling gaps

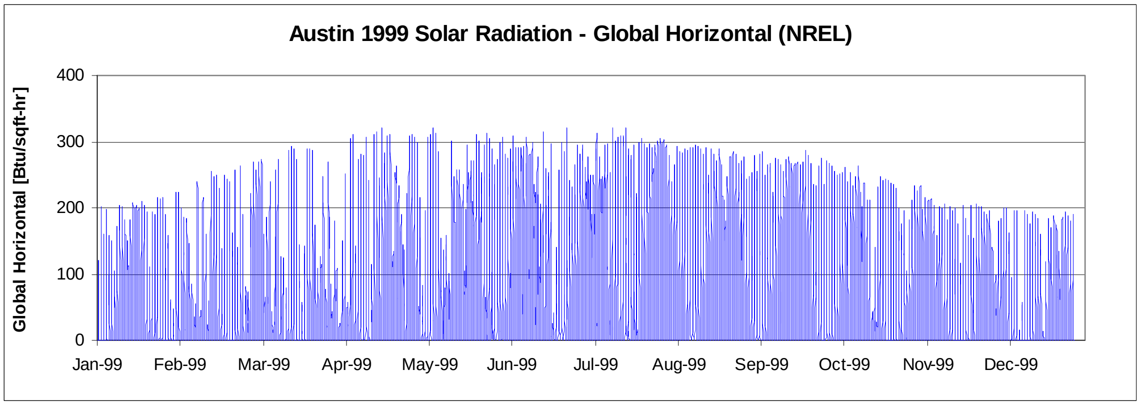





ATT 1999 Dew Point Temperature (NOAA)
Tdp [°F]
0
20
40
60
80
100
120
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


ATT 1999 Wind Speed (NOAA)
Wind Speed [Knots]
0
10
20
30
40
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


ATT 1999 Precipitation (NOAA)
Total Precip. [Inches]
0.0
1.0
2.0
3.0
4.0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99



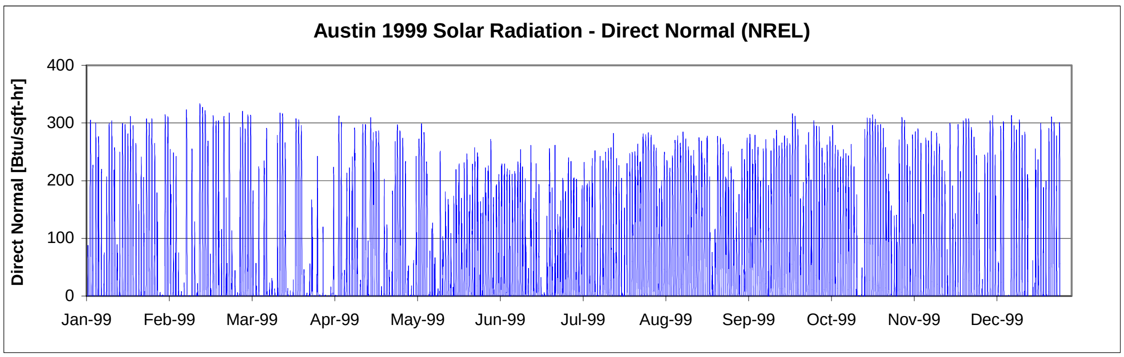


Figure 79: 1999 Hourly Weather Data (Austin Area -NOAA ATT site).

2.5.1.9 El Paso Area (NOAA ELP site)

1. Weather data source

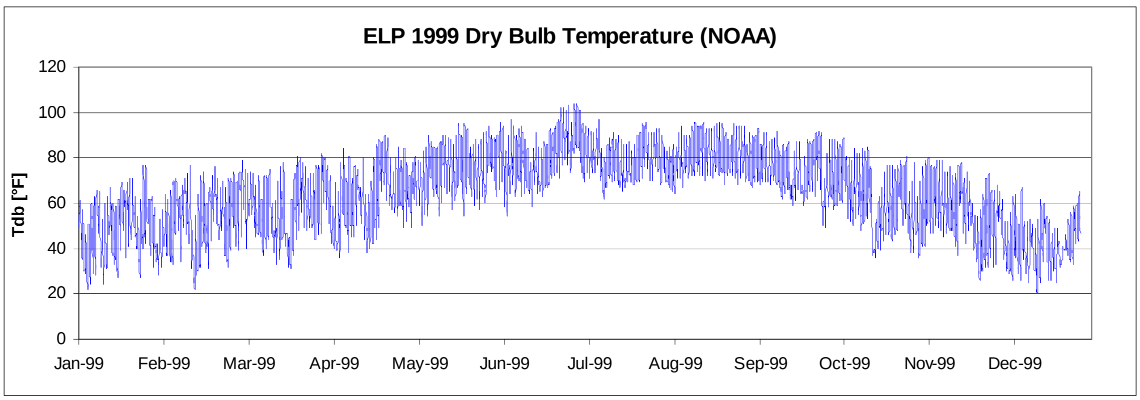
- Weather Station: El Paso International Airport (ELP), NOAA
- Solar Station: C12-EI Paso UTEP, TCEQ

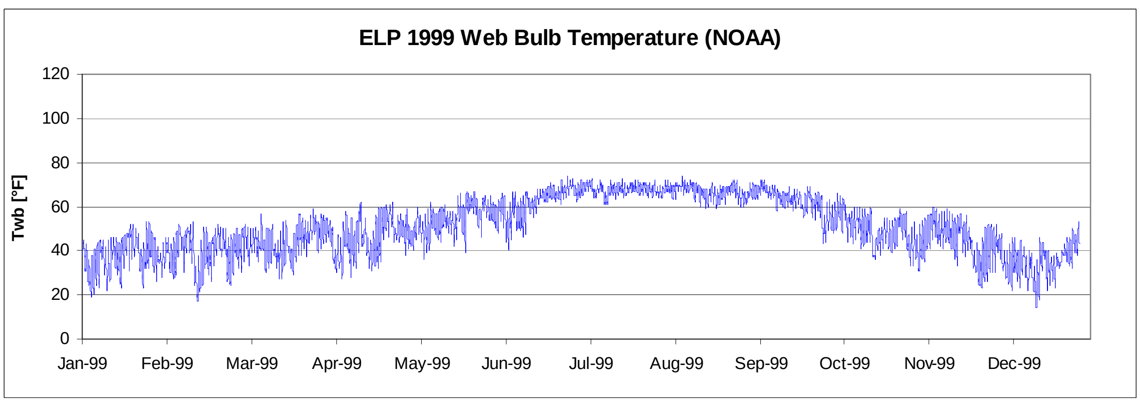
2. Summary of missing data

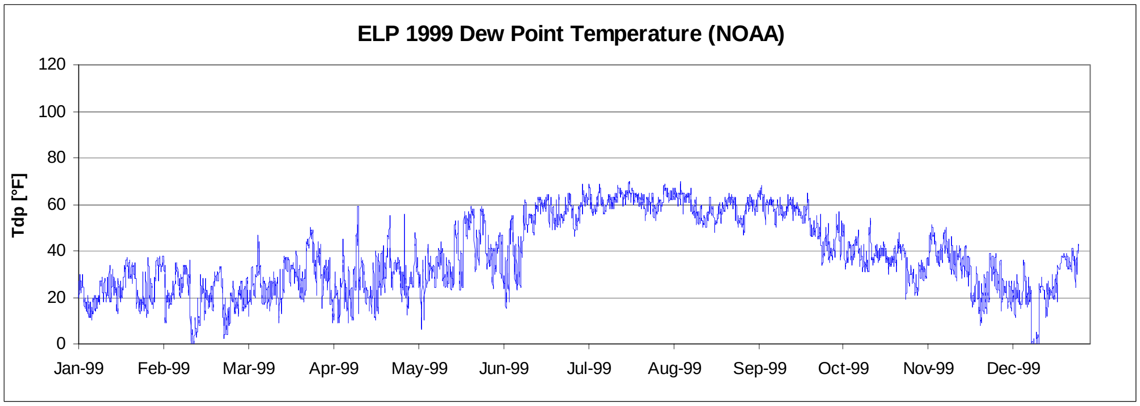
Station Name	Data Source	Data Type	# of Hours Missing Data (less than 6 hours)	# of Hours Missing Data (more than 6 hours)
C12-El Paso	TCEQ	Global	2	0
ELP	NOAA	Dry bulb temperature	1	0
		Wet bulb temperature	0	0
		Dew point temperature	12	12
		Wind speed		
		total Precip		

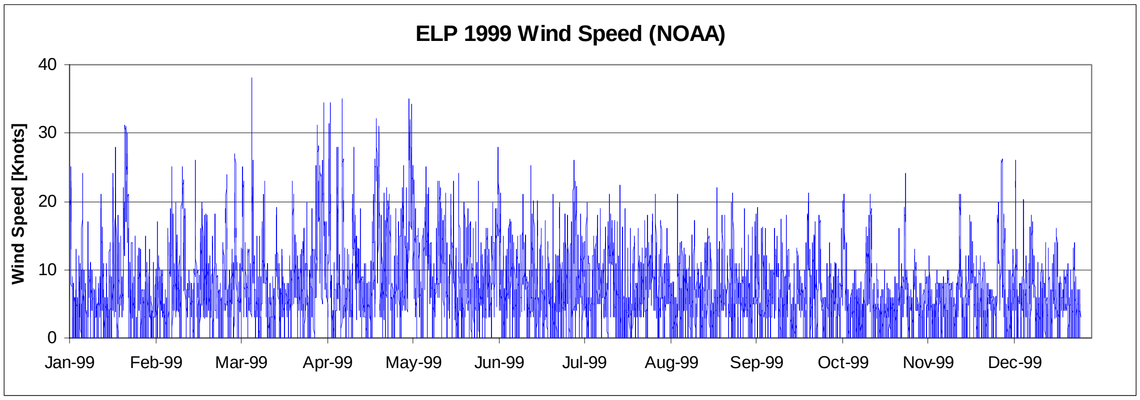
Table 58: Summary of Missing Data (El Paso Area -NOAA ELP site).

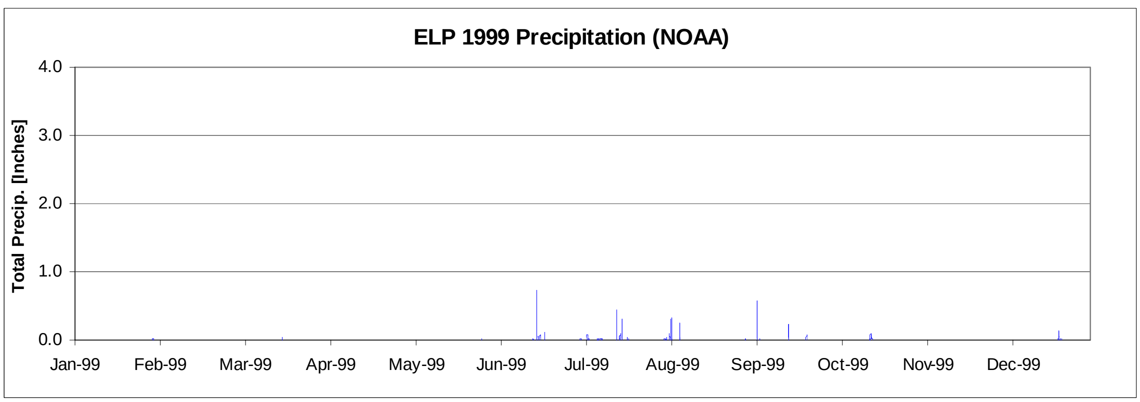
3. Time series plots for hourly weather data after filling gaps

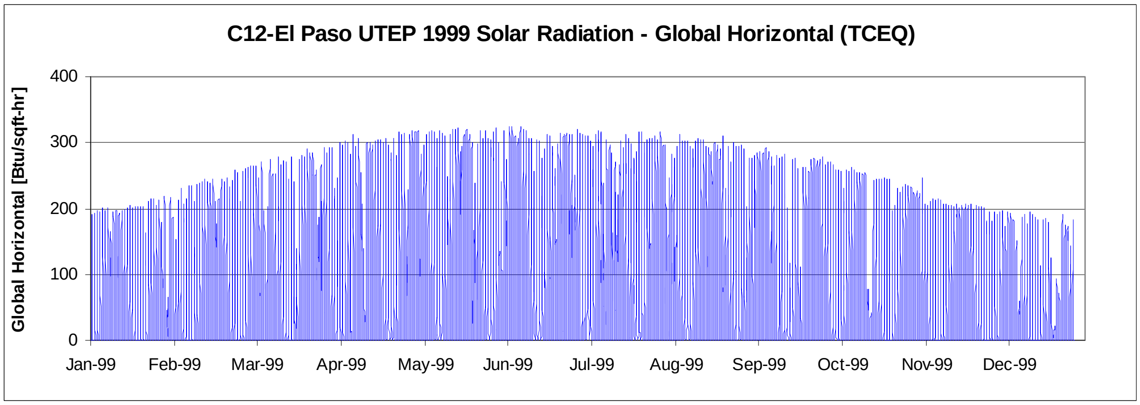





ELP 1999 Dew Point Temperature (NOAA)
Tdp [°F]
0
20
40
60
80
100
120
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


ELP 1999 Wind Speed (NOAA)
Wind Speed [Knots]
0
10
20
30
40
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99


ELP 1999 Precipitation (NOAA)
Total Precip. [Inches]
0.0
1.0
2.0
3.0
4.0
Jan-99
Feb-99
Mar-99
Apr-99
May-99
Jun-99
Jul-99
Aug-99
Sep-99
Oct-99
Nov-99
Dec-99



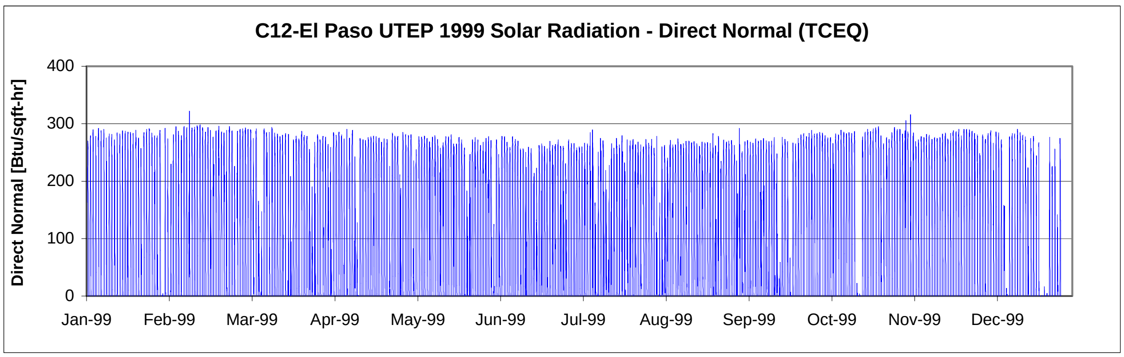


Figure 80: 1999 Hourly Weather Data (El Paso Area - NOAA ELP site).

2.5.2 1999 to 2003 Daily Weather data

The second set of weather files that needed to be assembled included daily average temperature, wind speed, and precipitation for the following sites:

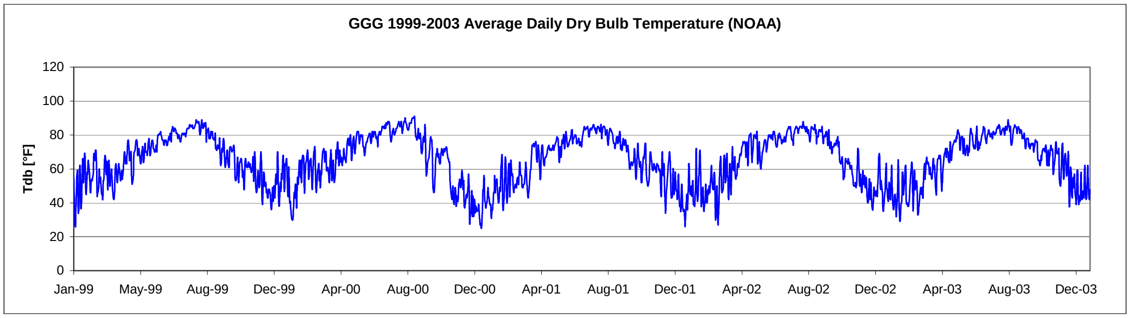
- Tyler/Longview Area (NOAA GGG data)
- Corpus Christi Area (NOAA CRP data)
- Dallas Ft. Worth Area (NOAA DFW data)
- Victoria area (NOAA VCT data)
- Beaumont – Port Arthur area (NOAA Port Arthur A.P. data)
- San Antonio area (NOAA SAT data)
- Houston/Galveston area (NOAA IAH data)
- Austin area (NOAA ATT site)
- El Paso area (NOAA ELP data)

These files were necessary for weather normalizing the analysis that used monthly utility billing data, which includes: municipal building retrofits, street lighting retrofits, traffic lighting retrofits, water and waste-water retrofits, and wind energy systems. New construction projects for street lights and traffic lights also used these data to weather normalize the peak daily use.

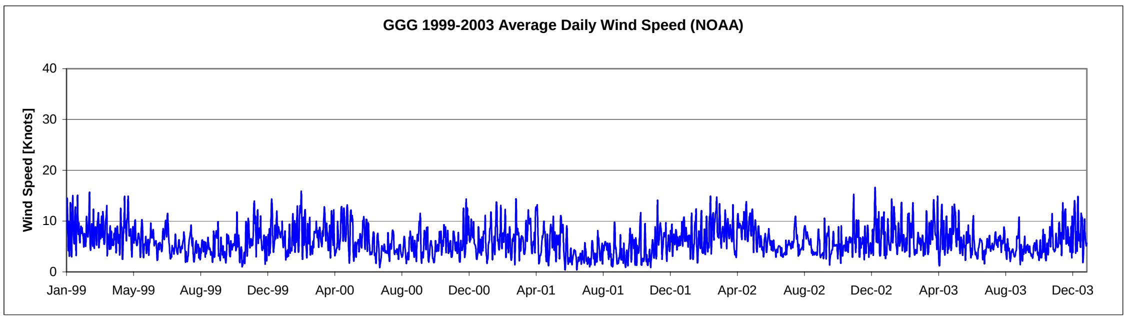
For each site, the hourly NOAA weather data were collected from January of 1999 through December of 2003. These hourly datasets were then inspected to determine the frequency and occurance of missing data. In cases where missing data existed, linear interpolation was used to fill in the missing temperature data. Missing wind data was filled with the data from the nearest NOAA site that contained data for the missing hour. Missing rainfall data were not filled. These data are used the by the emissions calculator to weather normalize the annual energy and peak-day energy use for those projects that utilize monthly utility billing data.

2.5.2.1 Tyler/Longview Area (NOAA GGG site)

1. Time series plot for average daily dry bulb temperature



2. Time series plot for average daily wind speed



3. Time series plot for daily total precipitation

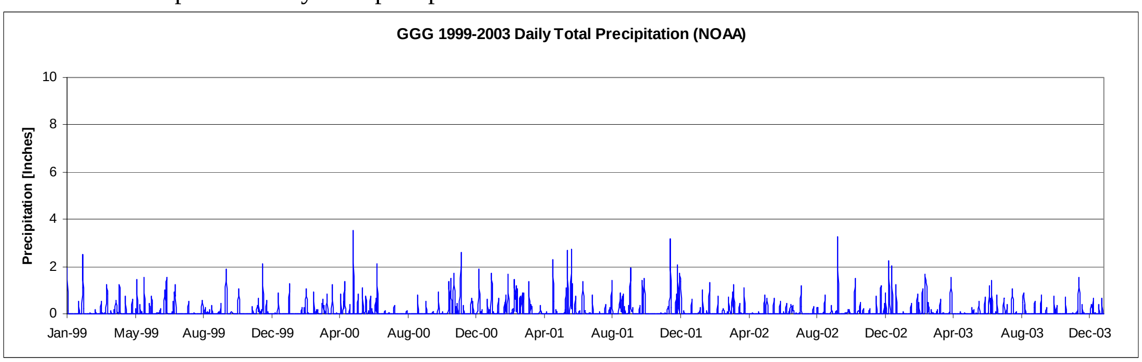
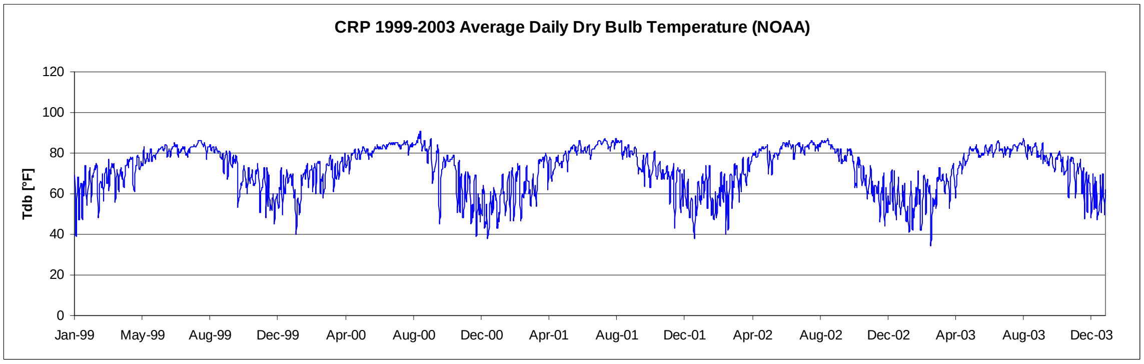


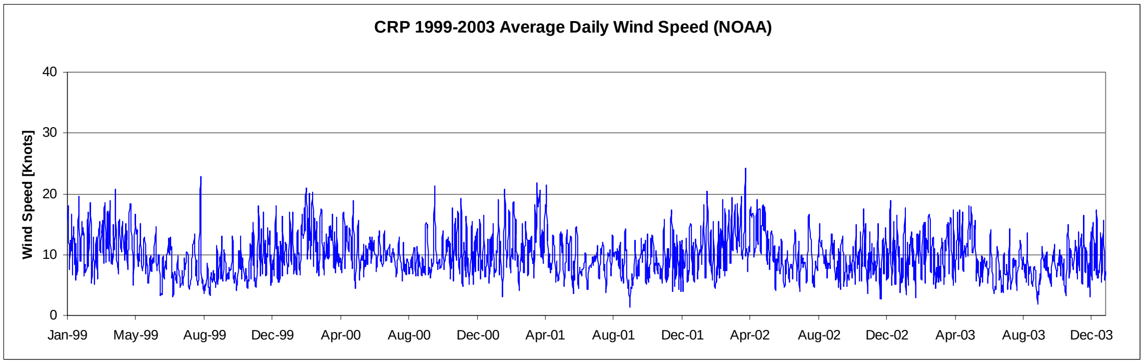
Figure 81: 1999 – 2003 Daily Weather Data (Tyler/Longview Area -NOAA GGG site).

2.5.2.2 Corpus Christi Area (NOAA CRP site)

1. Time series plot for average daily dry bulb temperature



2. Time series plot for average daily wind speed



3. Time series plot for daily total precipitation

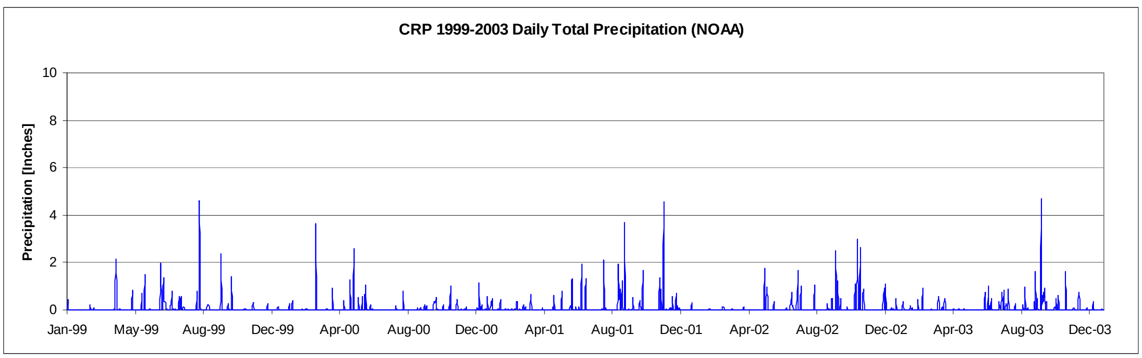
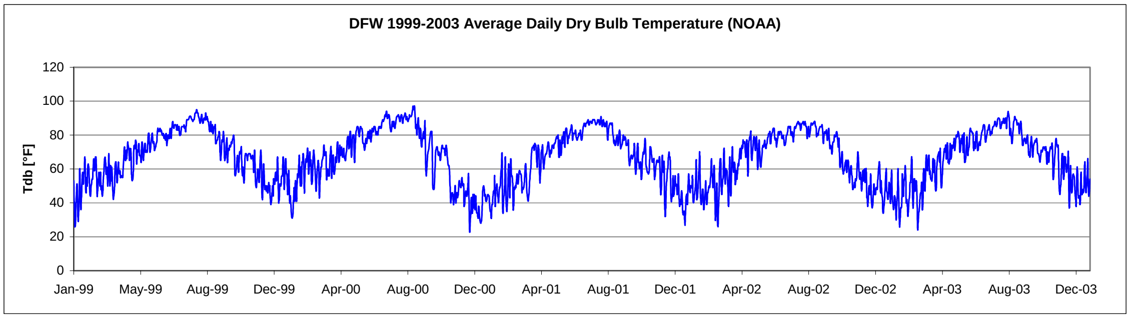


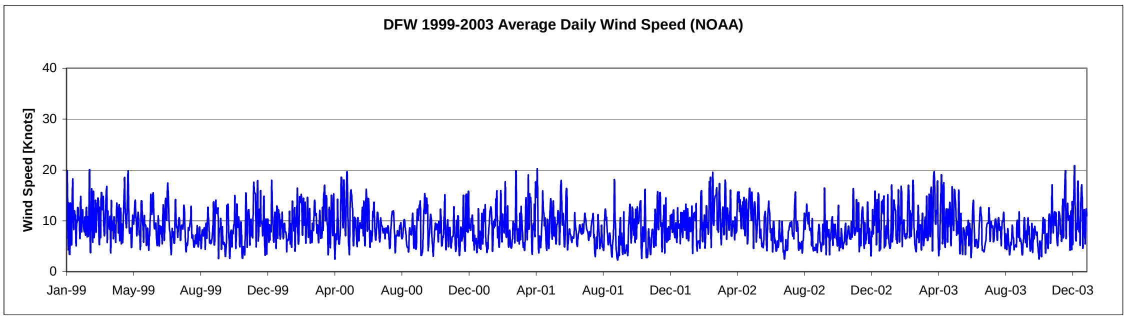
Figure 82: 1999 – 2003 Daily Weather Data (Corpus Christi Area NOAA CRP site).

2.5.2.3 Dallas-Ft. Worth Area (NOAA DFW site)

1. Time series plot for average daily dry bulb temperature



2. Time series plot for average daily wind speed



3. Time series plot for daily total precipitation

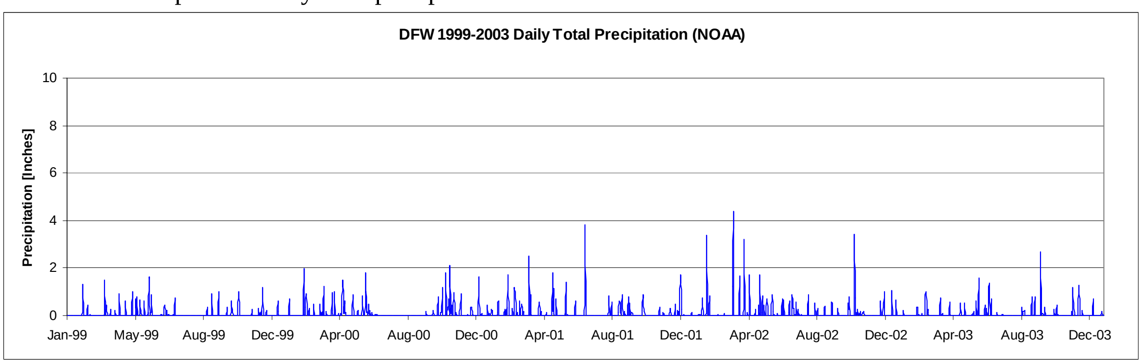
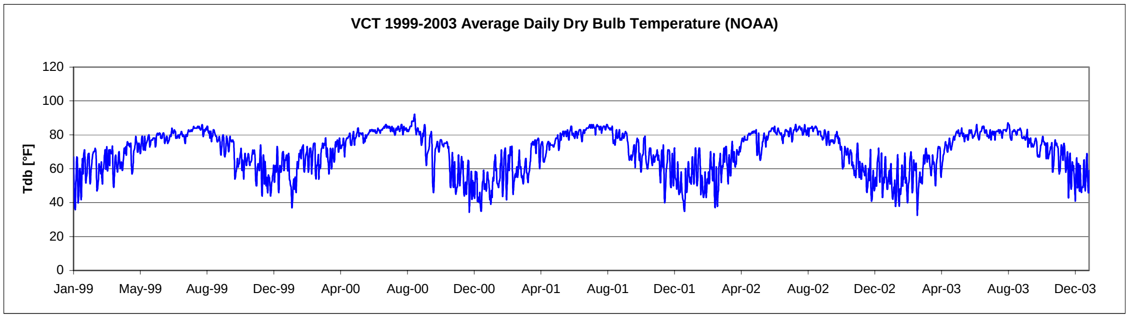


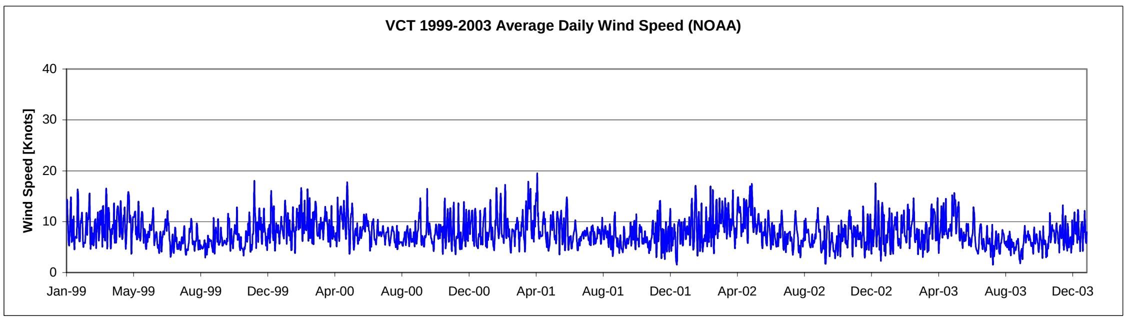
Figure 83: 1999 – 2003 Daily Weather Data (Dallas-Ft. Worth Area - NOAA DFW site).

2.5.2.4 Victoria Area (NOAA VCT site)

1. Time series plot for average daily dry bulb temperature



2. Time series plot for average daily wind speed



3. Time series plot for daily total precipitation

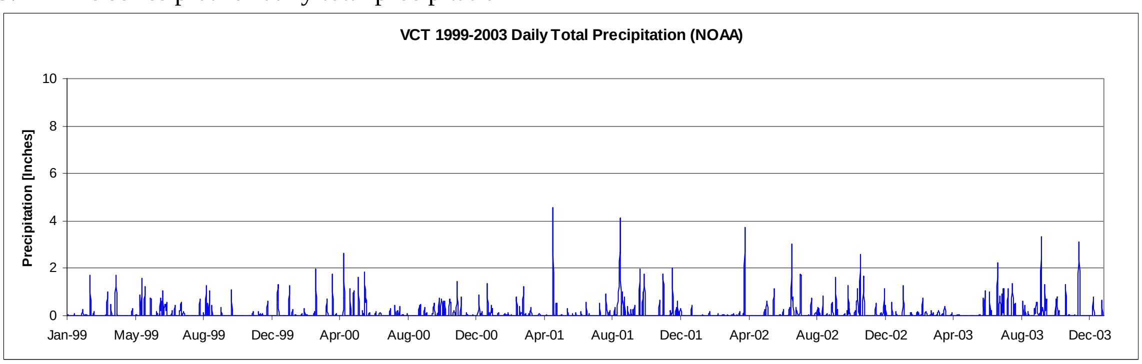
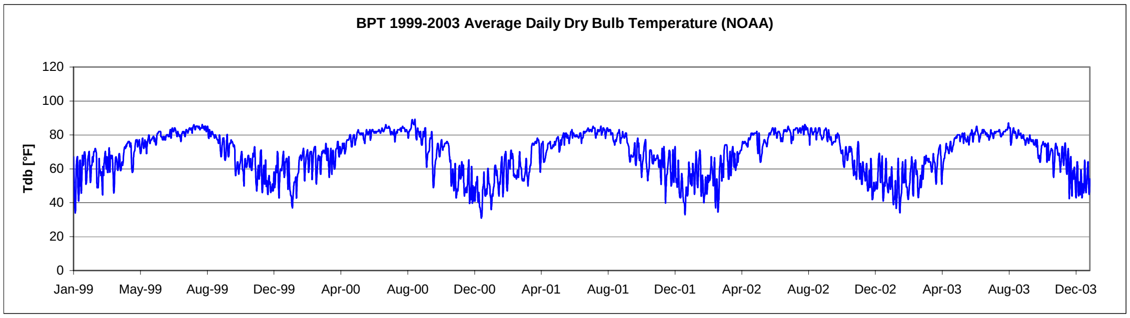


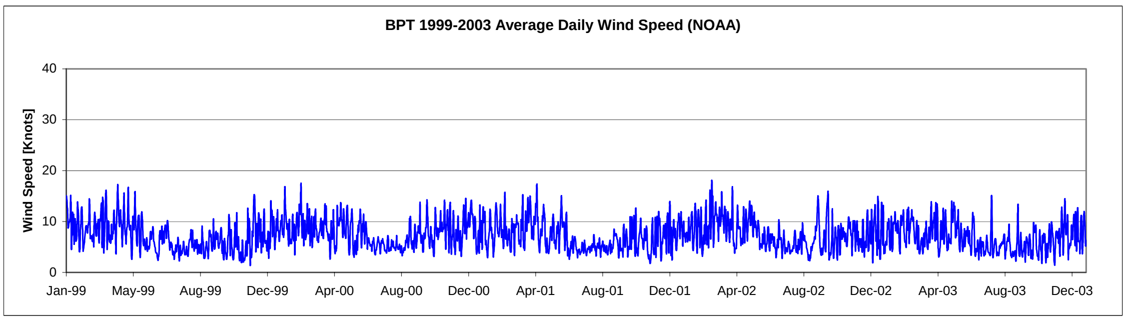
Figure 84: 1999 – 2003 Daily Weather Data (Victoria Area -NOAA VCT site).

2.5.2.5 Beaumont - Port Arthur Area (NOAA BPT site)

1. Time series plot for average daily dry bulb temperature



2. Time series plot for average daily wind speed



3. Time series plot for daily total precipitation

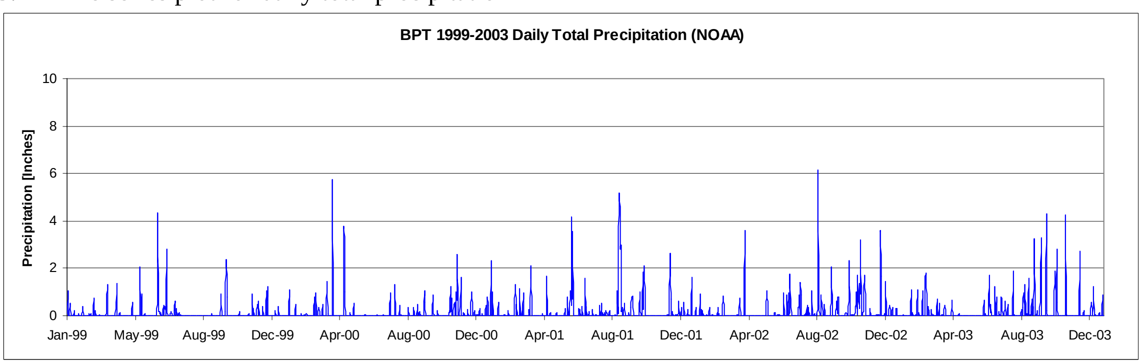
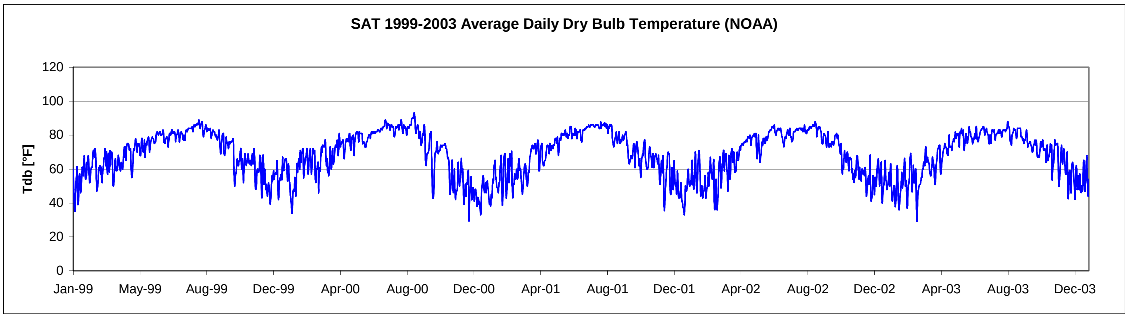


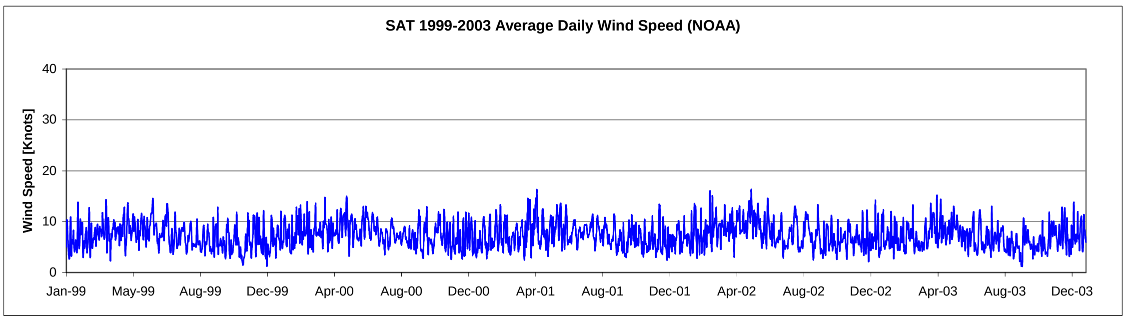
Figure 85: 1999 – 2003 Daily Weather Data (Beaumont / Port Arthur Area - NOAA BPT site).

2.5.2.6 San Antonio Area (NOAA SAT site)

1. Time series plot for average daily dry bulb temperature



2. Time series plot for average daily wind speed



3. Time series plot for daily total precipitation

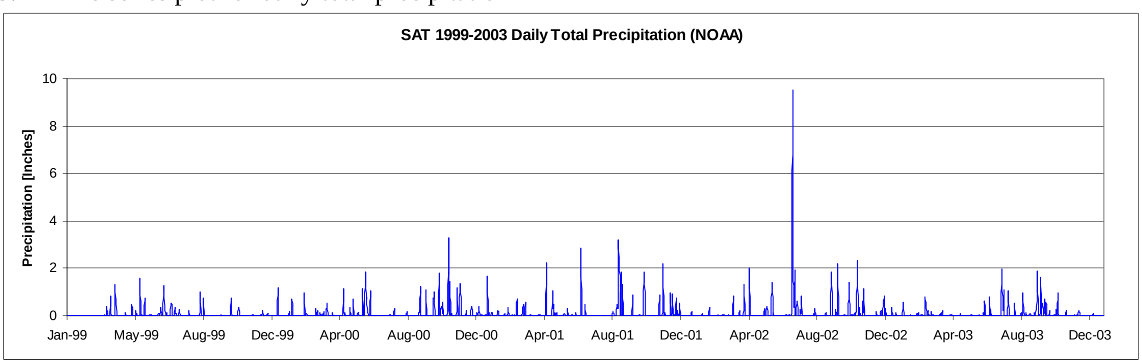
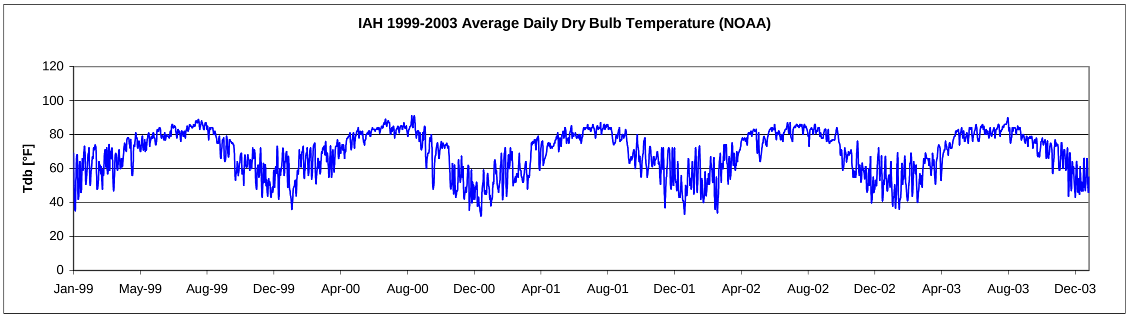


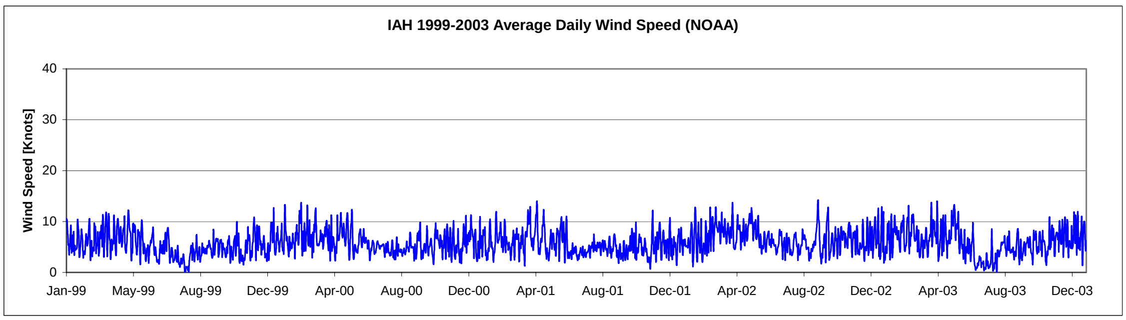
Figure 86: 1999 – 2003 Daily Weather Data (San Antonio Area - NOAA SAT site).

2.5.2.7 Houston/Galveston Area (NOAA IAH site)

1. Time series plot for average daily dry bulb temperature



2. Time series plot for average daily wind speed



3. Time series plot for daily total precipitation

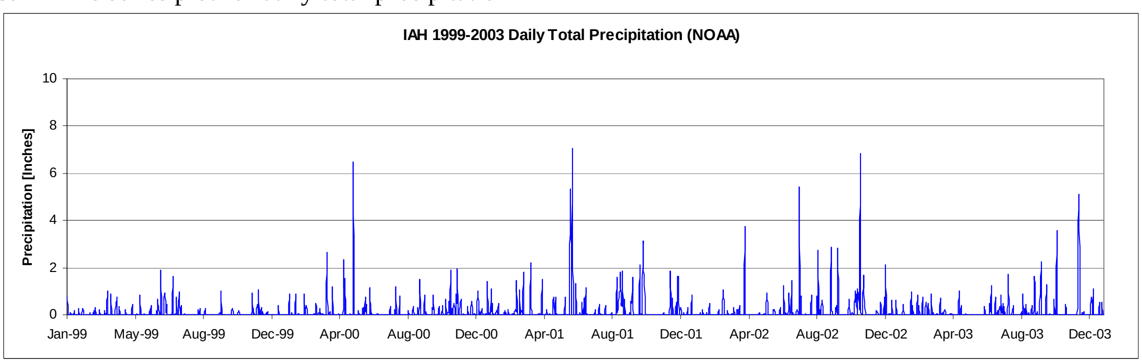
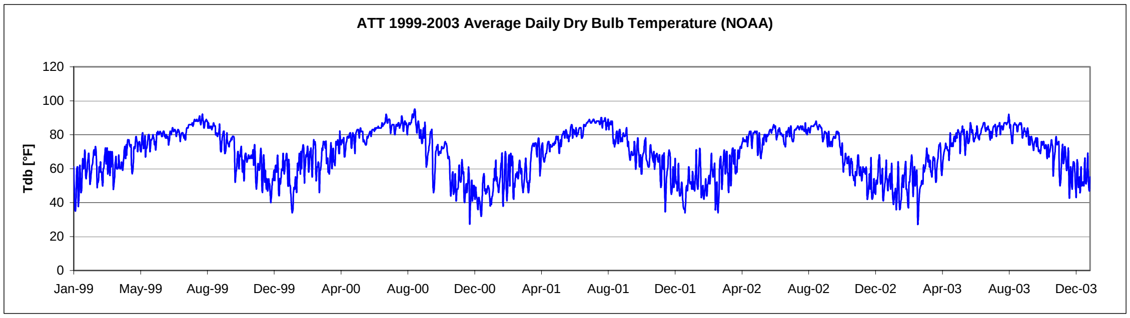


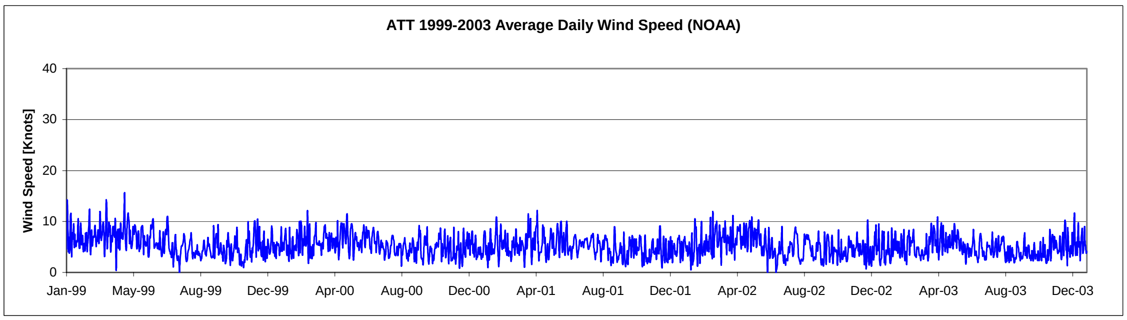
Figure 87: 1999 – 2003 Daily Weather Data (Houston/Galveston Area - NOAA IAH site).

2.5.2.8 Austin Area (NOAA ATT site)

1. Time series plot for average daily dry bulb temperature



2. Time series plot for average daily wind speed



3. Time series plot for daily total precipitation

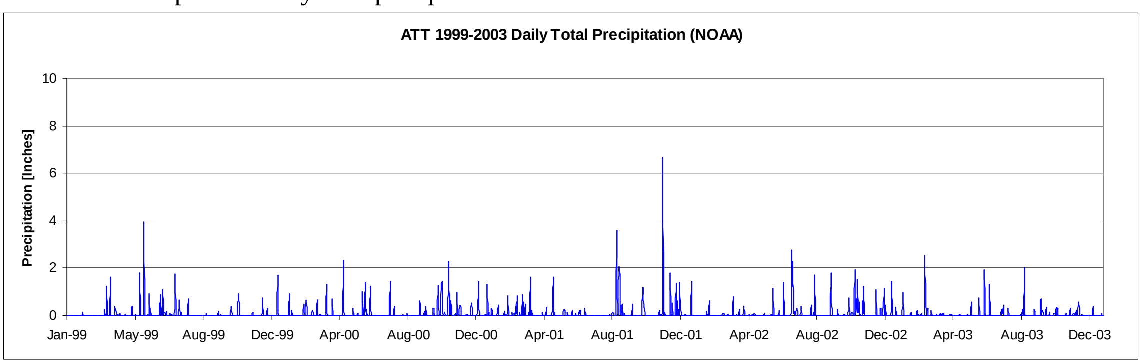
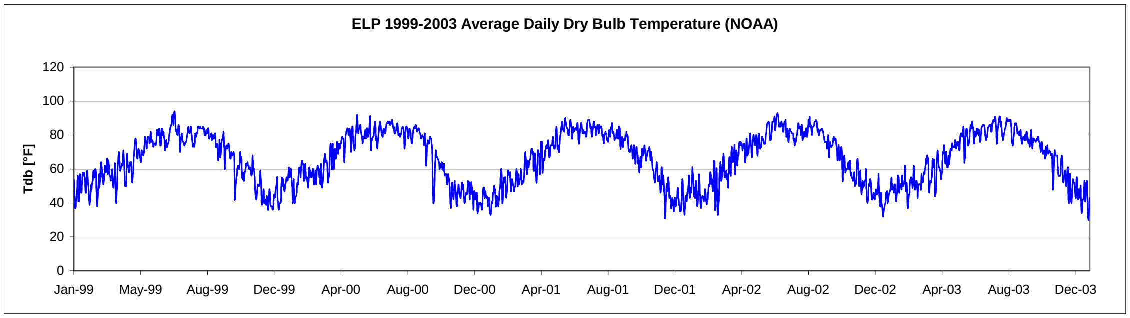


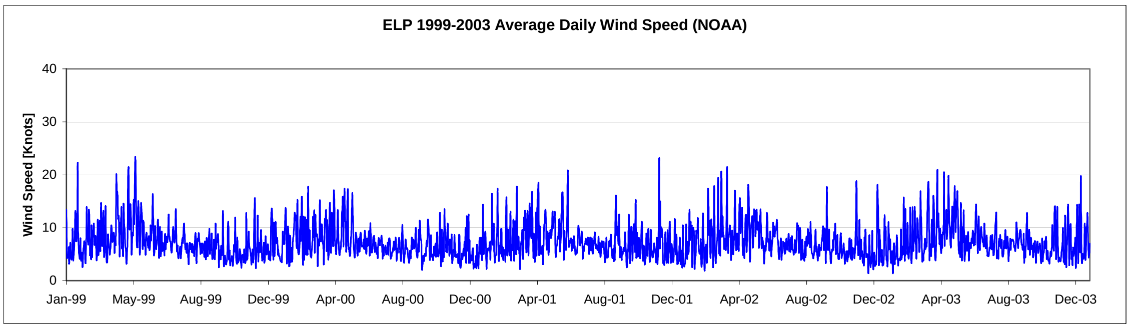
Figure 88: 1999 – 2003 Daily Weather Data (Austin Area - NOAA ATT site).

2.5.2.9 El Paso Area (NOAA ELP site)

1. Time series plot for average daily dry bulb temperature



2. Time series plot for average daily wind speed



3. Time series plot for daily total precipitation

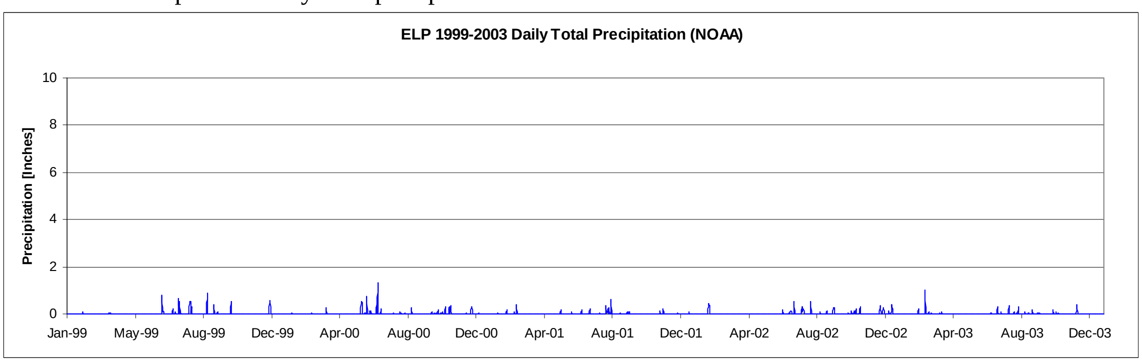


Figure 89: 1999 – 2003 Daily Weather Data (El Paso Area - NOAA ELP site).

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